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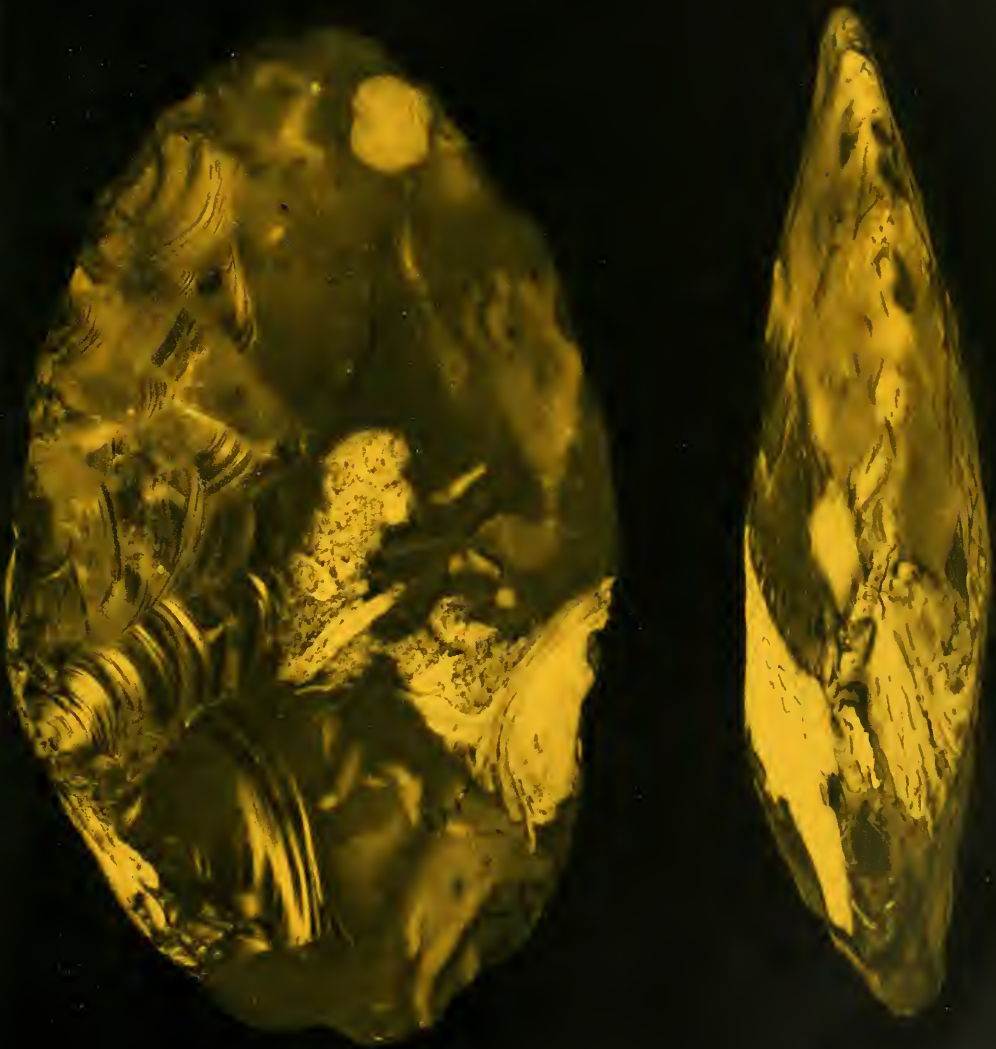

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Vol. LXVIII

NATURAL HISTORY

No. 1

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January 1959

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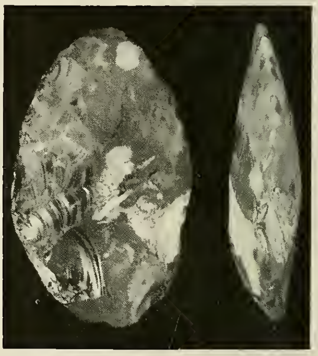

THE GOLDEN COLOR of this paleolithic tool, shown on the cover in a front and profile view, derives from the lighting — sodium vapor — used by the photographer to show all the fine detail of flaking.

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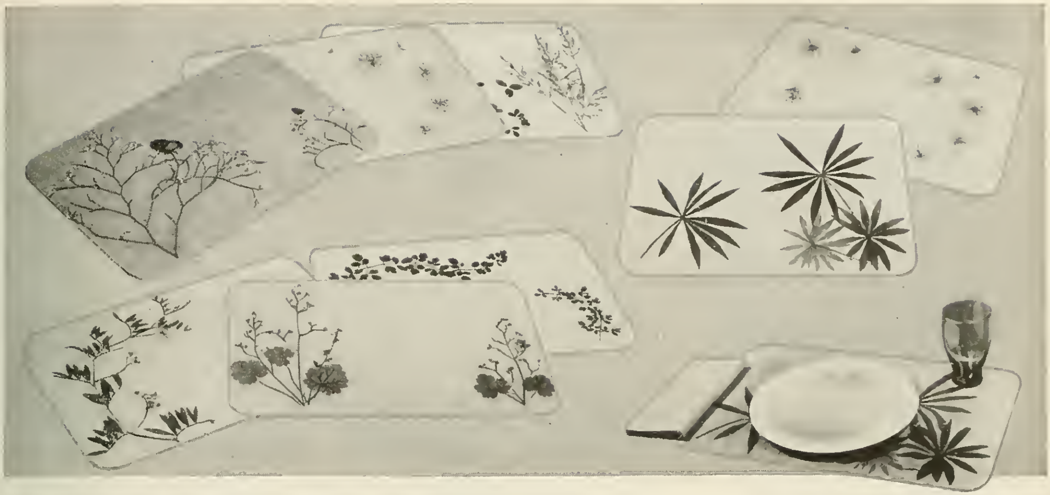

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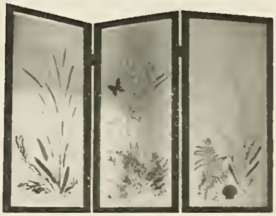

Here is another one of Nancy Hutchings' enchanting screen designs. These were featured in the September-October issue of CRAFT HORIZONS. Detailed directions are available for 25¢ per copy.

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Reviews

WHO WATCHES THE BIRD WATCHERS?

By Christopher Gerould

AMONG THE SCIENCES, psychology often seems to occupy a uniquely uncomfortable position, spread-eagled like an incautious sailor between the bobbing rowboat of intuition and the terra firma of objective measurement and reproducible experiment. This dilemma, in fact, predates the science of psychology—it is at least as old as formal philosophy: how to build a bridge between the vivid activity of the mind (which we glimpse so tantalizingly in what we call consciousness) and the palpable physical world which includes our own bodies and the extraordinary electrochemical complex that serves us as a nervous system.

Where can we begin to look for a clue to this relationship? At which end of the bridge? Each school of psychology has its own answer, and all of them can be right, for the starting point makes little difference when one sets out to explore the unknown. Are the intuitive journeys of William James or Freud less valid or less valuable than the controlled experiments of Pavlov or the laboratory niceties of biochemists, endocrinologists and experimental psychologists? Quite simply, no one knows enough to say.

Of the many approaches to the mind–body problem, one of the most attractive is the indirect approach through the study of behavior. Careful examination and analysis of the way an individual acts and reacts should give clues to the pattern by which he does so. And, if a pattern can be firmly established, the mechanism itself can, perhaps, be identified and explored. Many apparently inaccessible problems in other sciences have yielded to such attacks. For the last forty years, the behavioral approach has preoccupied a number of scientists, not all of whom regard themselves as psychologists.

The first great impetus to the systematic study of behavior came from Pavlov's discovery of the process of conditioning, whereby irrelevant stimuli could be made to evoke reflex forms of behavior. For decades, dogs in Pavlov's laboratories duly salivated at the ringing of bells or the flashing of lights after a conditioning period when these alien stimuli were presented at the same time as their food.

Following Pavlov's lead, a "behavioristic" view of the mind gained quick popularity. The whole nervous and mental organization was regarded as a network of conditioned reflexes. The theory has obvious attractions, particularly since the conditioning process is as easily demonstrated and as specific as a simple chemical reaction. Such reproducible facts are hard to come by in psychological research. Further, the neat push-button nature of conditioning had a great appeal to scientists still under the influence of an earlier generation which devoutly believed that the answer to all the questions of nature would ultimately be solved in the terms of Newtonian mechanics. To be sure, by 1910 (when behaviorism was being formulated), the physicists knew better than this, but few psychologists of the period had occasion to inform themselves in the physical sciences.

In the years since then, the original, simple vision of behaviorism has become far more sophisticated: and, in the meanwhile, other workers have taken up the study of behavior from other angles. *Instinctive Behavior: The Development of a Modern Concept* (International Universities Press, $7.50) is a collection of papers written and published over a period of twenty years. They represent the development of a highly specialized approach to behavior which has come to be known as "ethology"—defined in the foreword of this book as the "science of racial characteristics." Essentially, this is taxonomy, carried into the field of behavior and psychology. Today, ethology may be considered, principally, to embrace the specialized studies of animal activities by members of the Lorenz-Tinbergen school.

When the group of European naturalists who developed the ethological approach began their work, some thirty years ago, it was almost inevitable that they should react to the work of Pavlov and the behaviorists. The latter had gone a long way toward setting up a model of the mind as a dense but systematically simple aggregation of push-button mechanisms. Push the proper stimulus button and out pops the proper response. Push two buttons simultaneously, repeatedly, and *presto*! a conditioned reflex.

But (as became apparent later, when men began to build electronic analogues

A LEADER of the school of ethologists, Dr. Konrad Lorenz examines a duckling, *above*.

of this sort of brain) such a machine is not a mind. Too many abilities and properties are completely left out, and, above all, too many observed types of behavior cannot conceivably emerge from so unsophisticated an organ.

Some behaviorists stressed the learning process as the basis of "mind," the single conditioned reflex ramifying and multiplying into complex patterns. The ethologists, in reaction, began by concentrating on precisely the kinds of behavior that, they felt, could not be produced by any sort of "living" computer. They examined and catalogued the behavior both of newborn animals and of animals that had grown from birth or from the egg in complete isolation from their own kind and their normal environment. Above all they looked for (and found) behavior patterns in their untaught and isolated subjects that exactly reproduced patterns in normally reared subjects of the same species.

The goal they sought, of course, lay at the opposite pole from the conditioned reflex. The ethologists were looking for innate behavior in its purest state: behavior that could not possibly have been *learned*, behavior that would be as uniquely typical of a particular species as a cockatoo's bill or a leopard's spots.

The detailed observations of this scientific group are fascinating to anyone with an interest in the way animals behave. Their work not only corroborated and refined the facts of species-typical behavior but also laid a solid foundation for continuing studies in comparative behavior that are as basic—and should ultimately be as rewarding—as those in the field of comparative anatomy.

But to many of the group, such obser-

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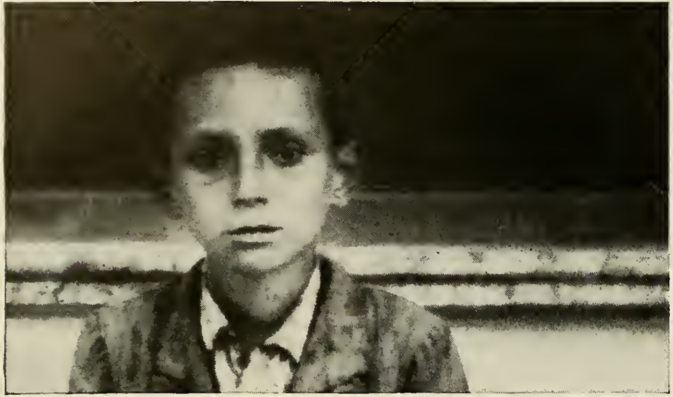

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Christos' parents were married just after the war when everyone hoped for a better future. Instead, Communist inspired uprisings spread over the country. Christos' father, joined the National Guard and took part in many battles. When guerilla bands entered his village they destroyed his house and burned all his belongings.

Life for Christos' family began all over—from nothing. They now live in a hut with a roof of straw. They own three pieces of furniture. All must sleep on straw mats on the cold earthen floor. Their only property is a quarter acre of land which the father cultivates early in the morning and after dark. During the daylight hours he must work on other farmers' land for daily wages to buy food.

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A writer in the field of science for many years, Mr. Gerould regularly contributes reviews to this magazine.

vations and categorizations were not enough. Almost as soon as they had begun their observations, leading ethologists began to systematize and build a theory of "instinctive" behavior on the basis of their researches. It is with such theory that this book is chiefly concerned.

The theory of instinctive behavior proposed by Konrad Lorenz, Nicholas Tinbergen and the late Paul Schiller, its chief architects, sets up a mechanical analogue for the operation of instincts, largely opposed to the reflex theory.

Each instinctive or innate behavior response, in this view, is ready-formed in the nervous system in recognizable, although not always perfected, form. And each response pattern builds up behind it a potential of energy during periods of disuse—rather in the manner of water backing up behind a dam with the spillway closed.

Blocking the expression of each such behavior pattern is a highly specific "innate release mechanism" (IRM for short), acting like the valve in such a spillway. This mechanism is activated by more or less appropriate stimuli, called "releasers," which appear in the subject's environment. Once the releaser is sensed, the IRM operates and the pent-up energy flows through and activates the response pattern. In a typical example, the shape, size and marking of the parent bird's head acts as releaser (presumably innate) to set off the IRM that allows a nestling to express its inherited response of gaping to be fed.

These three concepts—the blocked or dammed-up response pattern, the IRM and the releaser—lie at the core of the theory, and most of this volume consists of arguments for their existence and validity. The growing potential of energy "behind" an unused response pattern is of particular importance, since the authors account for various types of unmotivated or mismotivated behavior in terms of a build-up of energy or pressure which breaks through the IRM like water breaching an overloaded dam.

The observed fact that repeated presentations of a releaser stimulus eventually results in a lessening or exhaustion of the behavior response leads the writers to extend the reservoir analogy. Under these circumstances, they say, the water level is down and the reservoir can yield no more.

A key principle in the position taken by this group is that each individual behavior system is genetically set—planted firmly in each animal as part of the

(Continued on page 53)

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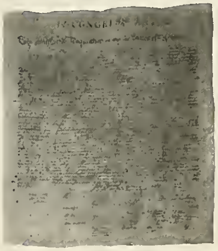

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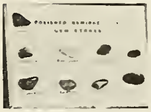

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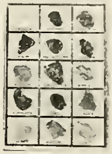

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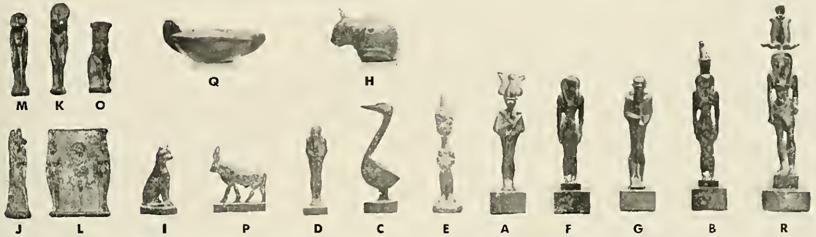

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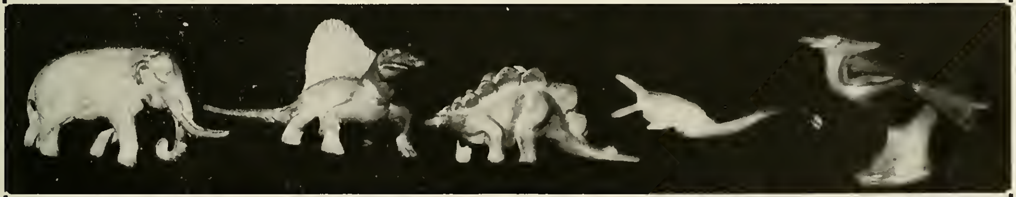

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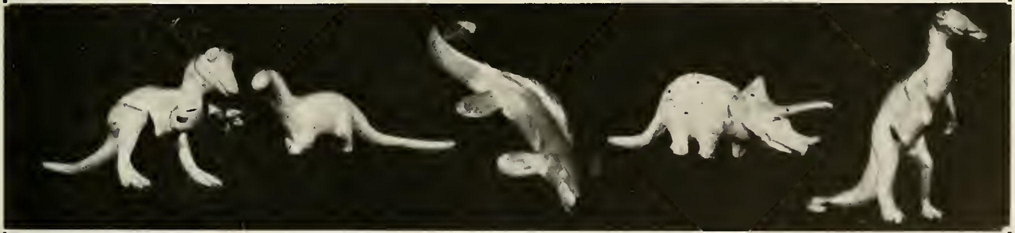

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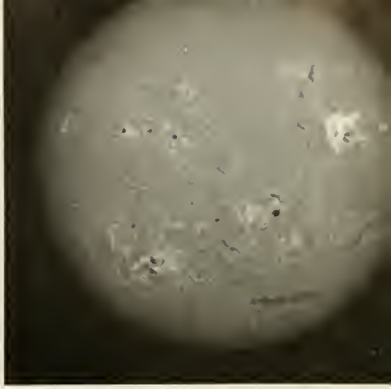
GEOPHYSICAL YEAR ENDS

After eighteen months of work, the scientists will need years to analyze the IGY's results

By Walter Sullivan


Solar flare was snapped by Swedish group on Capri in July, 1957, "alert."

IF THE PLANET EARTH is likened to a basketball, then the environment with which, until recently, man has had contact is but a paint-thin veneer over such a sphere. In the Pecos oil field of Texas, at last report, a well is down more than four miles—and is still drilling. But this would be a mere pinprick into the coat of paint over our basketball; and our view upwards is blurred by the ocean of air on whose floor, lobster-like, we maintain our existence.

Man's first concerted effort to explore his environment—from the high heavens to the most profound oceanic deep—is officially over. The International Geophysical Year came to an end December 31, even though many of its projects continue. The sun has passed the scheduled maximum of its eleven-year cycle of sunspot activity. Those who have been manning remote stations on drifting ice floes, barren atolls or isolated mountain tops are, many of them, headed home. Unfortunately, some will never return. Vast were the expeditionary efforts of the IGY and loss of life was probably inevitable. Men and horses plunged down crevasses. Tractor-drivers perished when their vehicles broke through the ice into polar waters. Planes crashed and scientists froze in blizzarding mountain fastnesses. Such tragedies, too often, have been the price of knowledge.

To most people, the IGY is memorable for sponsoring man's first penetration into space. The eyes of millions, dulled by the routine of roofed-over life, looked skyward and saw remote specks of light sail by—the earth satellites, guiding stars to the future of mankind.

The IGY lasted eighteen months, largely so that it would be sure to span an expected maximum of sunspot activity, but also to include several scheduled eclipses. Despite the attention devoted to the launching of Soviet and American satellites, much IGY work was in other fields. Research ships crisscrossed the oceans, lowering cameras or other instruments to depths of almost seven miles. Patient observers round the globe watched for flares on the sun or for displays of the aurora, or read instruments in air so cold that it could not be breathed raw.

The rockets and satellites were designed to lift the eyes of science above the atmosphere, which prevents us from seeing the true image of what lies beyond, for it shields the earth from the bulk of the radiation that reaches the atmosphere from space and the sun. We know now that the spectrum of this radiation is enormous, including radio waves, cosmic rays, ultraviolet, infrared and X-rays, as well as the narrow band of visible light that does get through — and hence, which we have learned to see.

In the physics lab of the State University of Iowa, in Iowa City, there is a tall room whose walls are lined with shelves, packed to the ceiling with rows of magnetic tapes. This represents the data collected from the Explorer satellites launched so far. Most of it has not yet been studied. Samplings have given a preliminary picture of radiation, cosmic rays and meteoric particles in space, but it may be years before all the data has been worked up and its meaning fully understood.

This situation applies to virtually all IGY results. We know there is about twice as much ice in Antarctica as had been thought before—which almost doubles the amount of ice in the world. We know that ice temperatures in a hole drilled 1,000 feet into the antarctic ice sheet get colder with every few feet of increased depth below the surface layer, suggesting a steady warming since the days of Charlemagne. But the most important questions are still unanswered—even though we may now have the information that will ultimately enable someone to answer them.

A number of these questions concern the future. Will the present warming open the Arctic Ocean to year-round shipping? Will this happen before the century is out? Will that change, in turn, start a new ice age? What has caused the warming? How long will it continue? To what extent do events and cycles on the sun affect climate and weather changes on the earth?

A large proportion of the IGY effort was aimed, directly or indirectly, at these problems. Essentially, however, the target was knowledge of our environment, whether or not there was obvious practical application of the knowledge gained.

Here are a few of the discoveries:

SPACE

SO REFINED had the science of upper-air physics become, by the time that the first IGY satellites were launched, that few surprises were encountered. Rocket data had been extrapolated upward with such skill that the satellite results, in many cases, called for only minor revisions.

"MOON WATCHERS" waited for glimpse of satellites in New York City, *above.*

SOVIET STUDENTS undertook a similar watch for Sputniks in Moscow, *below.*

Although air density appeared to be ten times greater than previous estimates for the region between 100 and 300 miles up, the air at those levels is still so thin that, even when the earlier estimate was multiplied by ten, the result was thinner than what, by laboratory standards, is regarded as an effective vacuum.

There was, however, one important surprise—the "Van Allen radiation." The geiger counters of the first Explorer satellite fell silent when the vehicle got up to the highest part of its orbit. Yet, cosmic radiation was expected to increase gradually with altitude. Why, then, was there virtual silence, so far as radiation at these levels was concerned?

Dr. James A. Van Allen, of the State University of Iowa—who was in charge of the study—suspected that his orbiting geiger counters were being swamped by radiation beyond their counting capacity. By sending up an instrument capable of recording far more intense radiation, he was able to confirm his suspicion. Preliminary study indicates that the radiation—at least below the satellite ceiling (1,375 miles)—is concentrated over the earth's geomagnetic equator (*see* illustration, p. 18).

WATER

RESEARCH SHIPS of many nations sought clues to the part the oceans play in climate change. What was known of the circulating fluid which covers two-thirds of our planet was limited, by and large, to the thinnest skim of its surface. Yet, as with the air, one needed the whole picture, including the nature of the currents that creep far below the surface, to understand the role the oceans play in the earth's climate.

So vast was this job that the IGY only marked its beginning. The maritime nations of East and West have agreed to keep at it. They plan a concerted effort in the Indian Ocean —least studied of the major seas— during the years 1961-62.

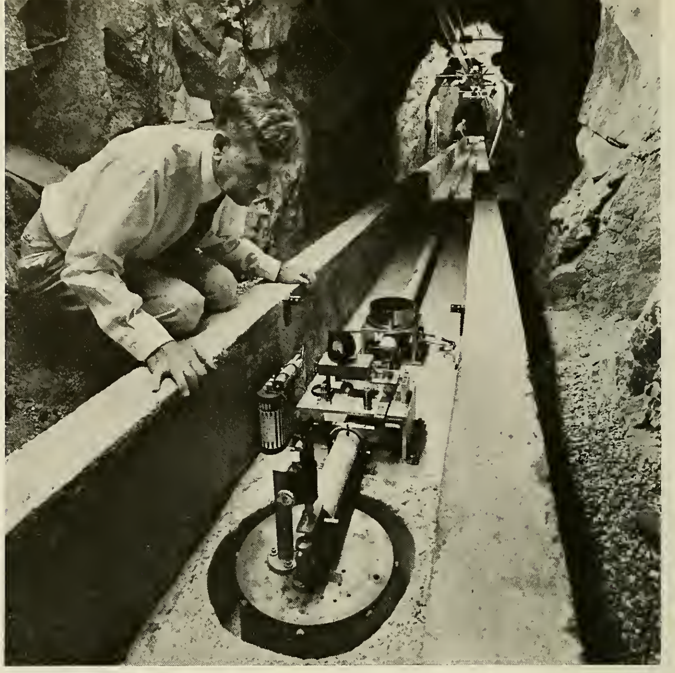
Although the IGY did not produce a complete picture, it brought some startling oceanic discoveries. In the Pacific, a mighty subsurface current

---

MR. SULLIVAN, of *The New York Times*, has traveled far and wide during the past eighteen months, covering a variety of IGY events.

Satellite's passage is marked by the luminous streak among the stars, *top*, in a time exposure made at Whittier, California. This is Sputnik II, as it appeared soon after its launching, with a canine passenger, in November, 1957.

ATMOSPHERIC HEIGHTS were examined by use of combination rocket balloon.



THE EARTH'S CRUST underwent study in numerous ways. Underground in California, this strain seismometer is being checked by Dr. Hugo Benihoff.

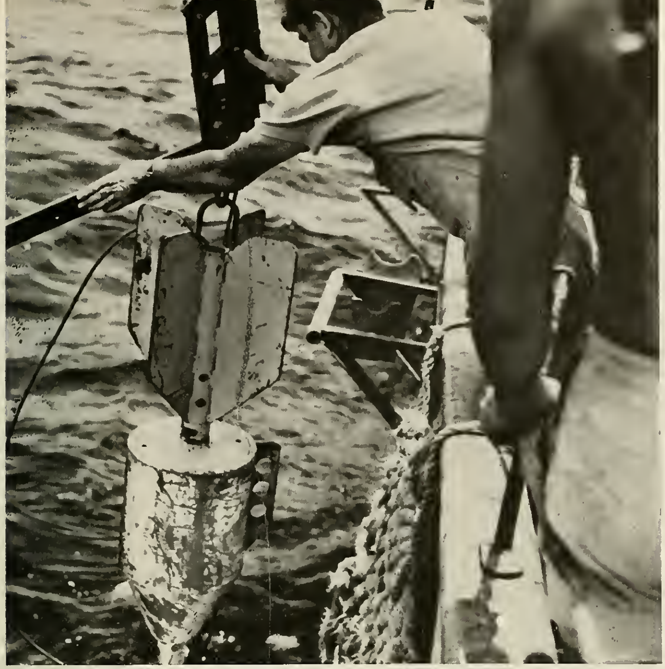
was traced for 3,500 miles. Possibly it is twice that long and its flow is likened to "a thousand Mississippis." It is a countercurrent, lying from 100 to 800 feet below the surface water, which flows westward—in the opposite direction—as the South Equatorial Current. The newly discovered Pacific current flows at three miles an hour—triple the speed of the surface current. Below both was found a third current, flowing gently west. The measurements were made—to depths of more than 3,000 feet—by the University of California's Scripps Institution of Oceanography.

Ships of the Woods Hole Oceanographic Institution, from Columbia University's Lamont Geological Observatory and from the Agricultural and Mechanical College of Texas roamed the Atlantic, studying the ocean floor and changes in chemical composition of the sea in recent decades. One of the tasks of the IGY ships was to study the carbon dioxide in the air and water. It was suspected by some that the present trend of climate might be man-made: that it was due to the "greenhouse effect" of carbon dioxide from the vast amounts of fuel consumed each year throughout the world. Carbon dioxide lets the sun's heat reach the earth, but inhibits its radiation back into the cold of space.

Oceans absorb this gas, but can they do so fast enough to neutralize the effect of all our factory chimneys and exhaust pipes? Little data from the past is available for comparison. Nevertheless, researchers reported strikingly uniform concentrations throughout the Pacific, regardless of distance from inhabited areas. At one point, detection instruments on a research ship showed a sudden rise in carbon dioxide over a short distance. Investigation revealed that a coal-burning ship had passed that way a few hours before.

ICE

IN SEEKING to learn what causes ice ages, one obvious place to look is among the glaciers and ice sheets still to be found in the world. Hence, glaciology was one of the primary areas of IGY study. Expeditions ventured into mountain areas from pole to pole. By far the largest effort was in Antarctica, where eleven nations established some two-score bases.



Sea's depths were plumbed by such instruments as this coring apparatus, which rams tube into the ocean floor, brings up samples of bottom sediments.

In addition, there were many little-publicized expeditions: the Poles in Spitsbergen, the Indians in the Himalayas, Americans in the Brooks Range of Alaska and the Olympic Range of Washington, Russians in Siberia and the Pamirs.

The work in the Brooks Range, the northernmost mountains of the North American mainland, showed that glaciers there grow fastest in summer, supporting the argument that what makes an ice age is not just cold, but—far more important—humidity. For no matter how cold it is, no ice sheet is built without snow. The summer winds over the Brooks Range were moisture-laden, whereas the winter winds, when the nearby Arctic Ocean is largely frozen, were dry. According to a theory now being discussed widely, it is an enlargement of this phenomenon which has accounted for the successive ice advances of the past million years: when the Arctic Ocean is ice-free, it produces moist air and hence new continental ice sheets. When it freezes over, the growth of ice sheets ends.

To study the "metabolism" of the Arctic Ocean, the United States and the Soviet Union each maintained two stations on ice, drifting here and there with the whims of wind and current. One of the American stations was on T-3 (also known as Fletcher's Ice Island), which had been occupied as a research station before the IGY. Unlike the thin floes that cover most of the Arctic Ocean, T-3 was a substantial platter of ice—about 150 feet thick through a large part of its area. The Russians occupied another such substantial ice island.

Both the Russian and American scientists, however, manned ice floes as well. These are only some seven feet thick and, although sometimes several square miles in area, may break up. Polar bears proved to be a problem to the men of both nations. The Soviet floe station reported bears close to the North Pole itself, showing how far from shore these animals wander. And, at one point, the Americans found that their runway lights would not switch on when a plane was en route to drop them supplies. The villain in the case was a polar bear cub who had systematically knocked over all the lights.

Not long after this episode, the men found that their floe had cracked. As a result they had to haul their

LOOK Magazine Photo.

Polar wastes were closely examined. This snow-borer saw use in Antarctica.

"MINITRACK" antenna field is seen in aerial view, *right*. This is one of eleven built to trace IGY satellite flights.

GIANT "DISH," *above*, at U.S. Naval Research Laboratory's observatory in Maryland, was also used for solar studies.

huts and piles of supplies half a mile to a safer spot and relocate the air strip. In November, 1958, the floe split again, dividing the camp from the airfield. A rescue plane evacuated the men and their records.

A far more serious misadventure threatened the life of Dr. Albert P. Crary, chief field scientist of the American program in the Antarctic. He and a companion were lowering equipment down the ice cliffs flanking Kainan Bay, site of the present Little America. Suddenly there was a terrible roar. Crary's companion jumped back as a large section of the cliff broke loose and fell into the sea. Crary vanished into the foaming waters, only to bob up again among the ice fragments. He clambered aboard a baby berg—so small that he dared not stamp his feet to keep warm lest the lump roll over and pitch him back into the water. Crary was finally rescued by a party in a rubber life raft, which found him well out to sea.

SUN

FROM TIME TO TIME, there are vast eruptions on the sun, known as solar flares. An unmistakable relationship exists between these flares and events on the earth such as radio blackouts, the aurora, magnetic storms and earth currents (NATURAL HISTORY, November, 1958). Some believe the streams of particles ejected by the flares also affect weather. Others argue that the energies needed to influence weather are far too great for such a cause-and-effect relationship. As an example, all the nuclear weapons in the world would not release as much energy as is expended in the earth's thunderstorms over a two-day period.

ANTENNAS of a hundred designs were utilized during Year. Line of movable "dish" aerials in Australia, *above*, is designed for study of solar radiation.

Nevertheless, Dr. Walter Orr Roberts, of the University of Colorado, who headed the United States IGY program of solar studies, feels that he and his associates have found a relationship between solar flares and changes in weather patterns at the highest layer of IGY weather mapping. If so, this would presumably mean a predictable change in weather patterns during the eleven-year cycle of sunspot maximum and minimum.

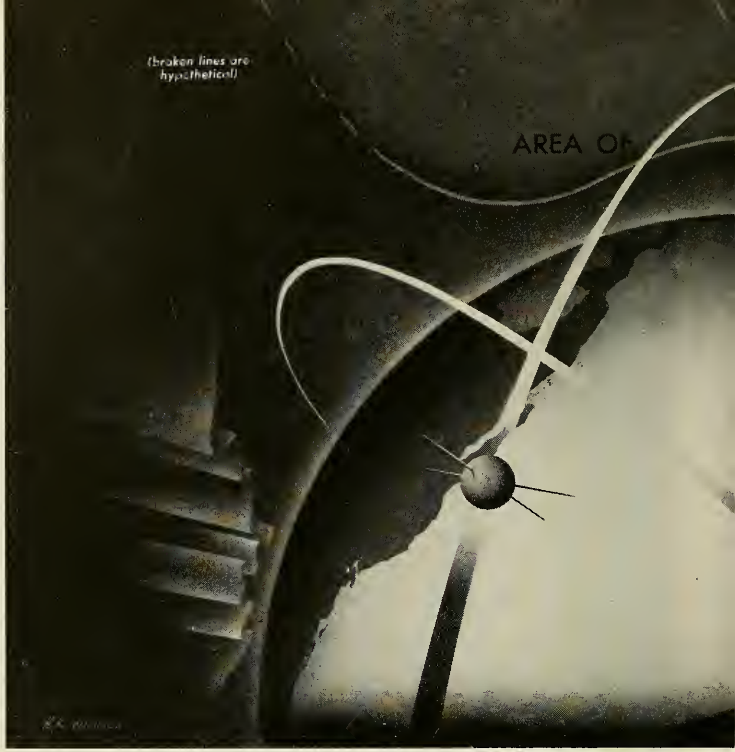
AIR

MAPPING of various layers of the weather over Antarctica revealed the patterns of air circulation above that continent for the first time. The work was done at a Weather Central established at Little America, with several foreign meteorologists—including a Russian—helping out. The United States Weather Bureau had a similar observer at Mirny, the chief Soviet Antarctic base. All previous records for cold were shattered, as had been expected, since no one before had wintered more than 100 miles from the tempering influence of the Antarctic Ocean. The highest and most remote station—the Russian outpost, Sovietskaya—reported readings as low as —125° F. A dozen miles up over the United States station at the South Pole, a balloon-borne radiosonde reported a reading of —135.4° F., the lowest ever recorded.

Much IGY research was directed at phenomena that take place in the upper, ionized layers of the atmosphere, most colorful of which are the displays of aurora. It had been thought that the direction in which these curtains of light "hang" in the sky is related to the direction of the earth's magnetic field. Yet, at Wilkes Station, in Antarctica, they were found to "hang" a different way almost every night. Since Wilkes is near the South Geomagnetic Pole, this variation may represent daily changes in the earth's field, but—as with much of scientific research—the new knowledge produced more unanswered questions.

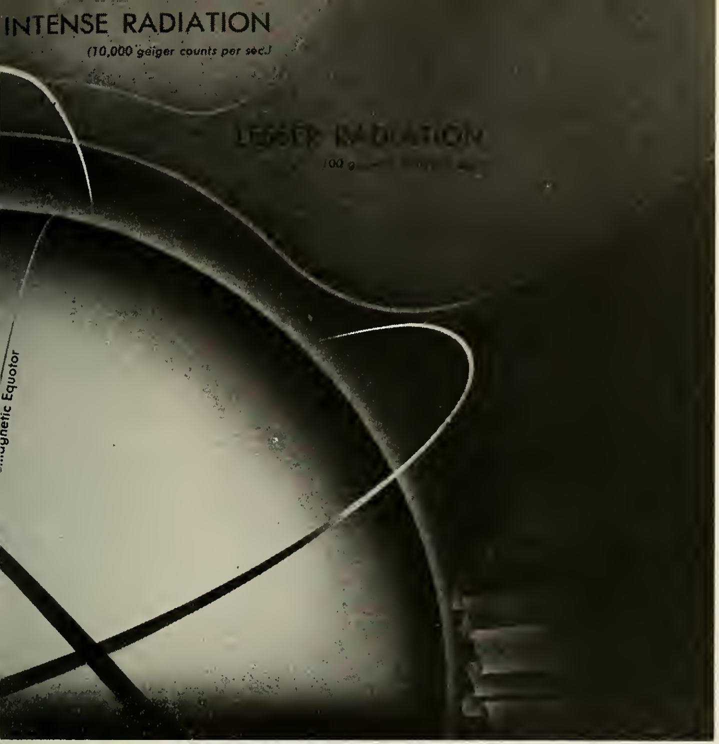
How high does the atmosphere go? IGY observations with rockets, satellites and ground-based instruments support the suspicion that there is no true space within the solar system: the earth, and possibly even planets more distant from the sun, orbit within a thin extension of the sun's own atmosphere. Defining the top of the earth's atmosphere therefore becomes a problem. Ninety-nine per cent of the air lies below the twenty-mile level, but the remaining one per cent seems to extend, by some definitions, for thousands of miles.

One suggestion is that if the top of the atmosphere is defined as the point where the earth's presence is responsible for the first alteration in the composition and temperature of the interplanetary medium, then this boundary is many earth radii distant—perhaps as far as 200,000 miles up.



ONE MAJOR FINDING from satellites' probes is the existence of previously unsuspected zones of radiation, close to the earth (outlined in the diagram,

MINOR SIDELIGHTS of the Year included such moments as these: *left*, a "bugged" egg is planted under a penguin;



above). Seemingly linked to the earth's own magnetic field, zones' boundaries are not yet known in detail. They may play a role in polar auroral displays.

The students of "whistlers" found support for this belief. Whistlers are radio signals—generated in nature by lightning—which travel back and forth, repeatedly, along the high-arching lines of the earth's magnetic field. The first concerted study of the phenomenon was carried out by a world-wide network of stations during the IGY. The signals were artificially propagated, and time signals from Washington, D.C., were received near Cape Horn (which lies at the opposite end of the theoretical arch of the earth's magnetic field, far in space). The time signals arrived first by the direct route, close to the earth's surface. A second later, they arrived via the far longer route through space.

COSMIC RAYS

PERHAPS the most perplexing messengers from space are cosmic rays, which strike our atmosphere with such energy that their fragments penetrate deep into the earth. Instruments to measure these rays in various ways were carried by IGY icebreakers in the polar regions, and by satellites, balloons, high-flying rockets and aircraft. Cosmic rays are deflected by the earth's magnetic field

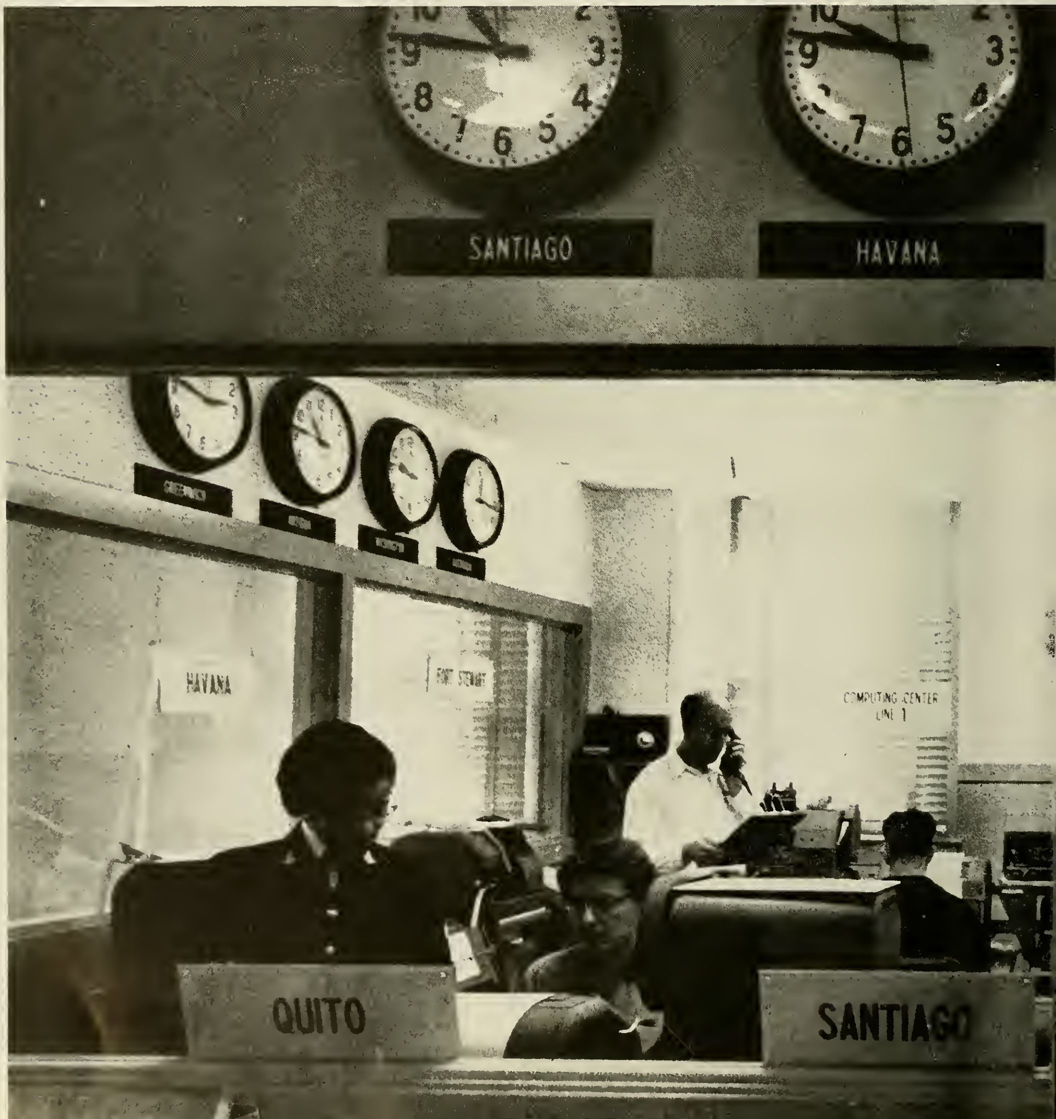
above, Sputnik triumph is symbolized by hula hoops; *right*, scientist poses for the press a long, cold way from home.

Year's end product—a mountain of paper work that will occupy scientists for years to come. *Above*, reports are microfilmed at IGY Center in Moscow.

in space in varying degrees, according to their energies. The more intense the field, the more they are deflected. Hence the varying intensity and composition of the rays, as they reach the earth, can be used to study the shape of the magnetic field in space, and its changes in terms of events on the sun.

At times, it was found, the variation of the rays with movement toward or away from the geomagnetic pole was so marked that even a shift of seven miles, one way or the other, was detectable. Of special interest was the change in this "latitude effect" when the effects of a solar flare reached the earth. To this end, a B-47 jet bomber was kept on constant alert at an Air Force base in Louisiana. Dr. John A. Simpson, at the University of Chicago, had a special telephone on his desk, wired into the air base switchboard. When his instruments sounded the alarm, he picked up the phone and made a call and the crew scrambled.

So successful was the IGY that there was strong pressure to continue the work at least another year. This for example, was the desire of the Soviet scientists. Others felt that science, so to speak, could



not sprint all the time. In some areas, IGY's unique tempo of exploration and co-operation would, it was agreed, be continued—in the Antarctic, in space and in oceanography. But many scientists—including those from the United States—felt they could not ask their governments for money to extend the full-scale program, since the original funds were granted for a one-time operation. Many researchers also looked with awe on the mountains of data already collected. It was wiser, they argued, to concentrate now on studying what they had, than to double the backlog.

The central budget of the IGY secretariat in Belgium was only a few hundred thousand dollars. Although the American scientific budget was a modest $39,000,000, this did not take into account the vast expenses of the satellite launchings, of military support for the polar expeditions or the large amounts indirectly contributed in the supporting work by universities and private institutes.

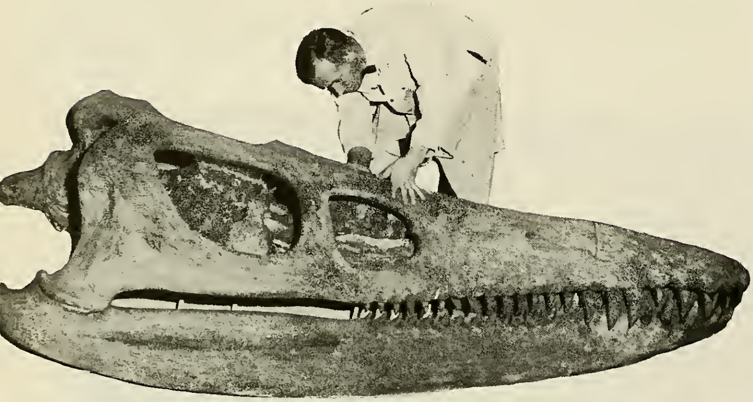
The total IGY expenditure by all nations probably runs into the hundreds of millions. But the returns on this investment will accrue throughout the space age—which began with the IGY, and now extends beyond all the horizons of our comprehension.

After Year's end, a vigil will be kept over earth satellites. Minitrack recordings are read, *above*; data sent on to computing center in code, *below*.

LIMA
SAN DIEGO
CAPE CANAVERAL
GRAND TURK
SAN DIEGO
ANTOFAGASTA

ANCIENT MONARCH OF THE SEAS

Kronosaurus queenslandicus, a fossil reptile, is at last on exhibition at Harvard



Huge head, some ten feet long, is studied by Harvard technician. Unlike *Kronosaurus,* other marine lizards had long necks that ended in small heads.

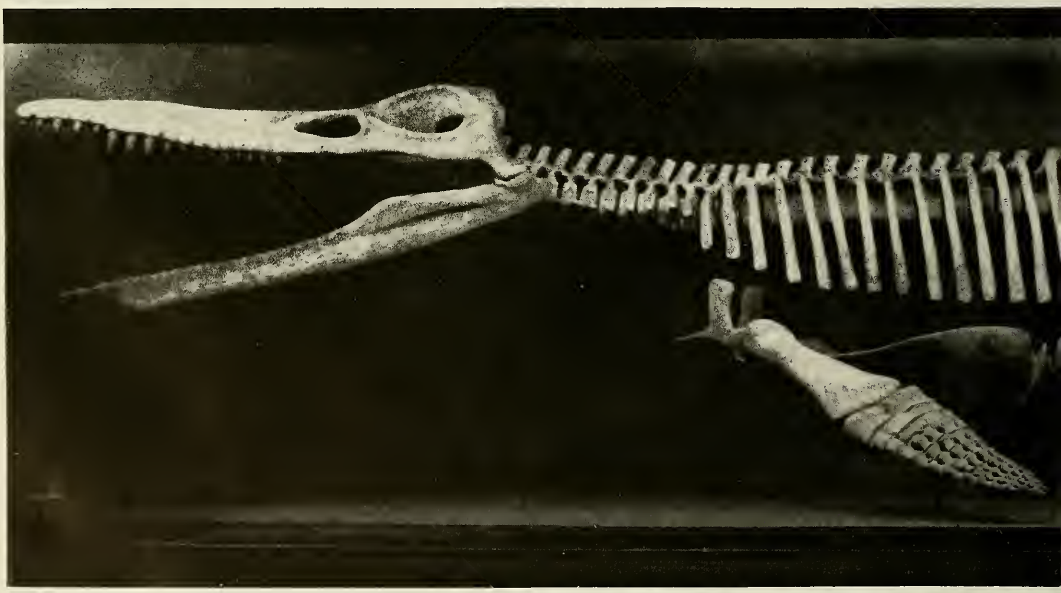
FOSSILS are a living—or, rather, a dead—reminder to the museum visitor that the millstones of evolution "grind exceeding slow." But he may not realize, seeing the finally prepared fossil on display, that museums move rather slowly, too.

If a reminder were needed, Harvard now offers it in a stunning exhibit at the Museum of Comparative Zoology: a complete skeleton of the giant marine lizard, *Kronosaurus queenslandicus.* Between the day when *Kronosaurus* sank to the bottom of a Cretaceous ocean and the final installation of his bones at the MCZ, a hundred millions years have elapsed.

The story begins, more precisely, in the Lower Cretaceous, when sediments drifting down to the ocean bottom entombed the creature's bones in limestone. In due course, the sea floor became part of continental Australia and the limestone began to be weathered by wind and water. Through the mantle of rock, bits of *Kronosaurus'* bones began to appear.

These were discovered on a Harvard expedition to Australia in 1931. Dynamite blasted the rock matrix apart; and the surviving blocks—weighing in at a total of nearly five tons—were shipped to Cambridge.

Here, a reversal of events took

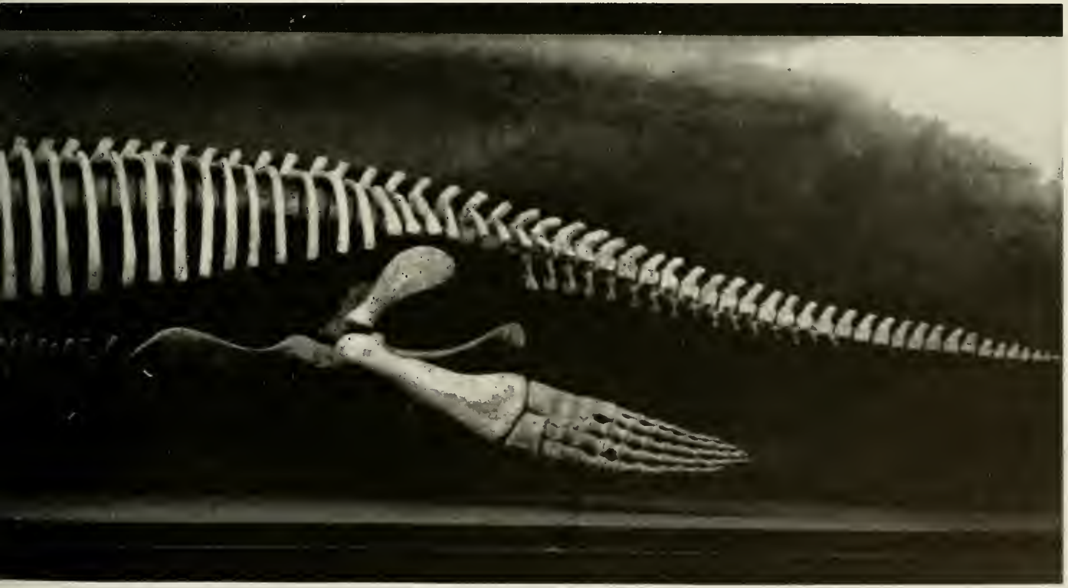


Complete skeleton as finally exhibited is supported by welded steel framework. Note the powerful limbs, further place: the reptile was entombed once more, this time in the depths of the Museum of Comparative Zoology, while the slow work of scientific exposure began. The reptile's fossilized bones were freed of the surrounding matrix and, after an acid bath, the ancient creature emerged—twenty-seven years after its arrival in the U.S.

Kronosaurus is one of the group of plesiosaurs, flesh-eating marine reptiles which have no real equivalent today and, in their time, had no exact counterpart on land, either. The plesiosaurs represent one of evolution's about-faces: after life had moved up from sea to land, this group returned to the ocean. Hence the great paddles they had for locomotion, and the long necks which enabled most of these massive mariners to snatch the fish they ate (although *Kronosaurus*, as it happens, has a short neck, and apparently made up for this by its very long head).

Why these beasts are called "plesiosaurs" i.e., "near reptiles," is something of a puzzle—the plesiosaur was thoroughly reptilian in aspect, and indeed has been described as a "snake, strung through the body of a turtle"—a statement the accuracy of which may be judged from the new exhibit to be seen at Harvard.

Preparing skeleton, technician chips limestone from bones with help of pick and hammer. Fossil bones were then immersed in acid bath for a cleaning.



specialized for rowing in water by the long toes: in land lizards, the toes normally have only five joints at the most.

CELESTIAL EVENTS

A selective calendar of astronomical occurrences in the first half of 1959

By K. L. Franklin

courtesy National Geograhic Society–Palomar Observatory Sky Survey ©

JANUARY

January 1
At 8:00 p.m. (EST), this date, the earth is at *perihelion*—the point in its orbit that lies *closest* to the sun. The two bodies are now separated by 91.5 million miles.

January 3
The Quadrantids—meteors that take their name from the obsolete constellation, Quadrans Muralis—should be on show tonight. Observers may see thirty to forty meteors an hour, radiating from a point low in the northeastern sky during the hours before dawn.

January 16
The moon—displayed in first-quarter phase in tonight's sky—is now nearly at its most distant point from the earth. For about a day, in consequence, the range between high and low tides will be rather small.

January 18
This night, just to the west of the Pleiades—in the constellation of Taurus (top of photograph, *left*)—a bright object will be visible near the moon. It is the planet Mars, in the constellation of Aries.

January 31
Observers in the southern United States can witness an occultation of Neptune by the moon (*see box, below*).

FEBRUARY

February 14
Mercury, beyond the sun, is now farthest removed from the earth for this season—129 million miles away.

OCCULTATIONS OF NEPTUNE

During 1959, Neptune will be occulted by the moon on several occasions. Almost three billion miles distant from the sun, our seventh planet is invisible to the unaided eye (it is about the eighth magnitude). A telescope—or binocular having objective lenses two or more inches in diameter—must be used to observe Neptune.

Until September, 1959, someone on the earth will be able to see an occultation of Neptune each month. The occultations listed below will be visible to observers in the southern United States: others may witness a very close approach of the moon to Neptune on these dates; all times, EST:

January 31: 6.51 a.m.
April 23: 5:26 a.m.
March 26: 9:00 p.m.
June 16: 11:44 p.m.

MARCH

March 1
In the morning sky, this day, the very bright object near the moon is Jupiter—the fifth planet, and the largest in our solar system. At this moment, both Jupiter and the moon are in the constellation of Libra.

March 11
The sun sets about 6:00 p.m. Although the moon is often the brighest object in the sky, only sharp eyes will detect the moon's thin crescent in the bright twilight—low in the west and very close to Venus, which will outshine it. Observers living south of 29°, by using binocular or telescope, can see an occultation of Venus by the moon a little after 6:30 p.m. (EST).

March 21
At 3:55 a.m. (EST), the sun crosses the equator into the northern sky, marking the start of *Spring* for the northern hemisphere (and *Autumn* "down under").

March 24
A partial eclipse of the moon will be visible generally in the eastern hemisphere (but *not* in the United States).

March 29
Mercury has reversed its February position. Now it lies *between* the earth and the sun, 56 million miles away.

APRIL

April 7
An annular eclipse of the sun will be visible on this date, but only in the wilds of central Australia.

April 23
On this date, the moon reaches full phase at a period when it is closest to the earth. For about a day, low tides will be exceptionally low and the high tides unusually high.

April 26
Set your clocks *ahead* one hour this day (Daylight Saving Time begins in many areas). Then look for Mercury, rising in the east just before dawn. It will seem to "double" the eastern side of the Great Square in Pegasus.

MAY

May 18
Jupiter lies directly south at midnight, in the constellation of Libra. The bright, red star to the south and east of Jupiter is Antares (of the first magnitude).

May 21
The full moon comes close to Jupiter tonight. It will be at its closest at 1:43 a.m. (EDT) on Friday, May 22.

May 22
Again, the full phase of the moon coincides with an orbital position quite close to the earth. As in April, for about a day, tides will show extreme ranges.

JUNE

June 3
Mercury has made another half-swing since March. Again, it is beyond the sun, some 123 million miles away.

June 14
About 9:00 a.m. (EDT) this morning, Venus and Mars will be separated by less than one degree. When first visible, just after sunset in the western sky, they both will still be quite close together, in the constellation of Cancer.

June 21
At 11:50 p.m. (EDT), the sun will reach its most northerly point in the sky, the summer solstice. First day of *Summer*.

June 23
Venus, now almost 68 million miles distant from the earth, is as far east of the sun as it will be this year. Venus will now begin to approach the sun and, at the same time, it will appear even brighter to observers.

Dr. Franklin, of The American Museum-Hayden Planetarium, prepares this summary each six months.

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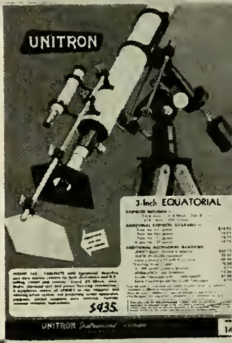
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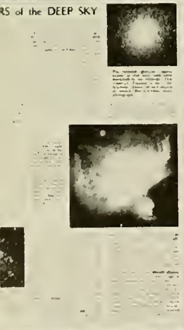
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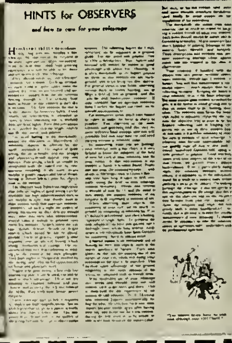
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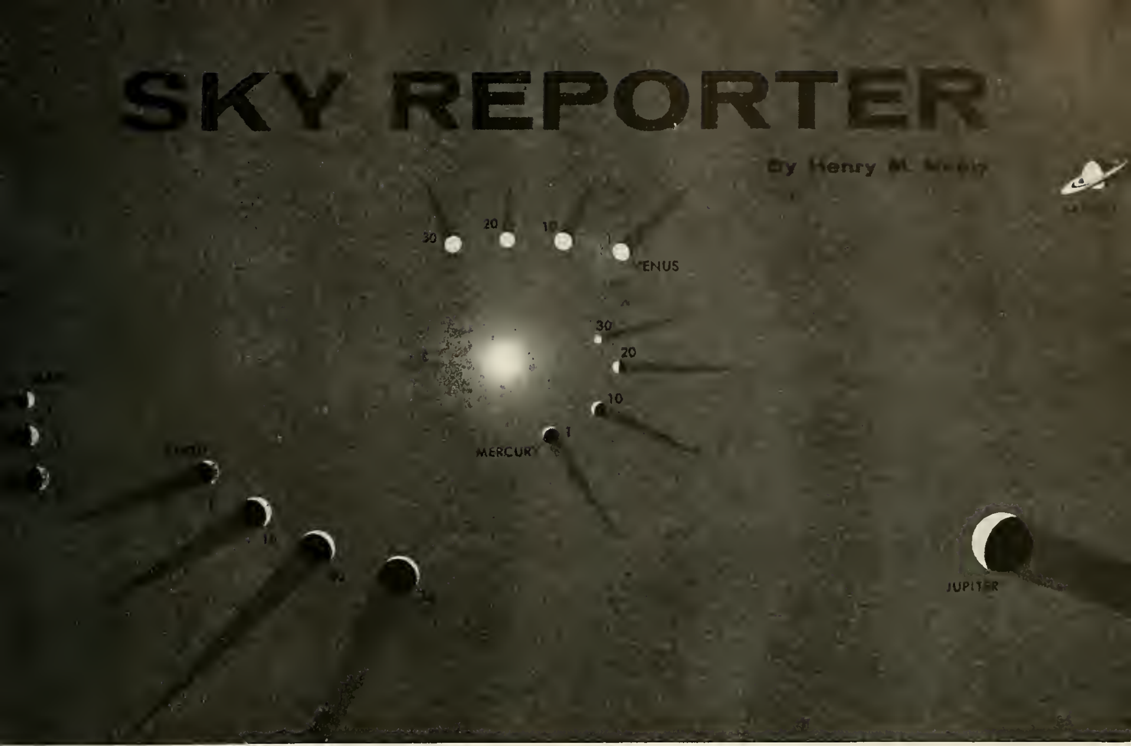
SKY REPORTER

By Henry M. Neely



IN THE FIRST MONTH of the year, it seems proper to start our review close to home—with the positions of the earth and its neighboring planets in their orbits around the sun *(above)*. Such a picture was last presented three months ago (NATURAL HISTORY, October, 1958) and readers may wish to compare the two illustrations.

From our imaginary observation point in space—above and to one side of the sun—it is easy to see that MERCURY will not long be visible this month. A line drawn between the positions of the earth and MERCURY, for January, will lie clear of the sun's glare. But, by January 10, this "line of sight" will lie far closer to the sun and, by January 20, MERCURY will be suffused in the solar glare.

While MERCURY is swinging "behind" the sun, VENUS is doing exactly the opposite. On January 1, the line of sight between the earth and VENUS lies too close to the sun for good observation. By the end of the month, however, the line of sight will be clear of the sun's glare. Then, stargazers will see VENUS as an "evening star," —a brilliant object over the western horizon after sunset.

The earth and MARS parted company on November 16 and we are now speeding away from the red planet. MARS is still a brilliant object in the night sky but, as the earth hurries off, increasing distance will make MARS constantly fainter until—by the end of January—the planet will appear no brighter than CAPELLA (overhead, on the map).

So far as the two remaining "naked eye" planets are concerned this month, the illustration makes it evident that the earth is now swinging closer to distant JUPITER and even more distant SATURN. During early January, dawn observers will find JUPITER well up over the southeast horizon by 6:00 A.M. Nearly two weeks of January will pass, however, before SATURN will show clearly. After January 15, early risers will see SATURN higher above the southeast horizon each dawn, following JUPITER.

BELOW, arranged in almanac fashion, is the month's SKY SCHEDULE—a list of some of the notable sights to watch for in the January heavens. Because NATURAL HISTORY, this month, also presents a list of celestial events for the first six months of 1959 *(see page 25)*, reference to that listing will complete the January roster.

JANUARY 1 to 10: as dawn begins, these mornings, MERCURY will be above the horizon, between east and southeast. It will be highest and best about 6:15 A.M. on January 1. Each morning thereafter, it will be a little lower and the chances of seeing it after January 7 are slim. Bright ANTARES, in the constellation of SCORPIUS, will be to the right of MERCURY and a little higher: MERCURY, however, will shine more brightly than ANTARES.

On January 4 and 5, the moon will introduce JUPITER. At 6:00 A.M., moon and planet will be about 20° high over the southwest horizon, the first magnitude star ANTARES below them. The old moon will be a thin crescent and not bright enough to interfere with observation. On January 4, the moon will be above JUPITER and, on the 5, a little lower and to the left.

JANUARY 11 to 20: dedicated "shooting star" enthusiasts —accustomed as they are to early dawn—may wish to try their luck with the mild, but sometimes interesting,

Mr. Neely, editor of *Sky Reporter* since 1947, now prepares this monthly feature for Natural History.

meteor shower—the Kappa Cygnids—on January 17. At 6:00 A.M.. watch over the northeast, about a third of the way up between horizon and zenith.

January 21 to 31: Saturn will be readily visible to early risers after January 25. By 6:00 A.M., the planet will stand 10° above the southeast horizon. Nor will Saturn be alone in the dawn sky: to the south *(right)* and more than twice as high above the horizon will be brilliant Jupiter. To trace the way from one to the other, start with Saturn and first pass to Antares—to the right and twice as high. Jupiter—higher and a bit farther to the right—is your next stop.

The trio of bright stars—Deneb in the constellation of Cygnus, Vega in the constellation of Lyra, and Altair in the constellation of Aquila—which we call the Summer Triangle, is also on display in the early morning sky. At the apex of the "triangle," Altair stands some 15° above the eastern horizon at 6:00 A.M.; bright Deneb—one of the two base stars—about 25° over the northeast; Vega—the other base—halfway up the sky, east–northeast.

Most planetarium lecturers can project an arrow of light on the darkened dome, to direct the audience's attention to some particular object in the "sky." Out of doors, the moon can serve as such a "pointer." The following list gives the names of the stars and constellations that the moon-pointer will help the beginner to identify, together with the best times for observing and the proper orientation of the roll-around map.

January 14-15. 8:30 to 9:30 P.M. (bottom of map between west and southwest). To the right of the waxing moon is the Great Square of Pegasus. The viewer can follow a string of fairly bright stars almost vertically up from Alpheratz, (one corner of the Square) through Mirach and Almach to Mirfak.

January 16-17. 8:25 to 9:25 P.M. (see bottom of map at the southwest). Above and to the left of the first-quarter moon, brilliant Mars will be unmistakable. And then, to the right of the moon will be seen the bright stars, Hamal and Sheratan.

January 18-19. 8:15 to 9:15 P.M. (bottom of map, as it is printed here, at south). The waxing moon has grown so bright now that it washes out the dimmer stars. But first magnitude Aldebaran, will be easily visible to the left of the moon and Mars to the right.

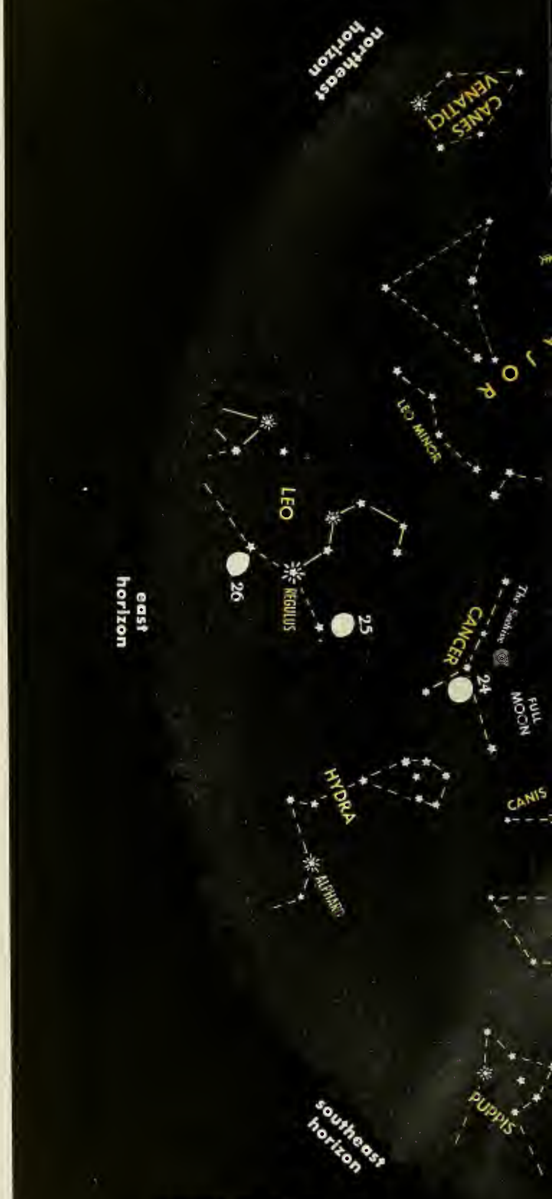
January 20-21. 8:10 to 9:10 P.M. (bottom of map between south and southeast). The brilliant stars, Betelgeuse and Rigel, in the constellation of Orion, will be visible beneath the moon, some 45° above the horizon.

January 22-23. 8:00 to 9:00 P.M. (bottom of map between southeast and east). Below the full moon and to the right, can be seen brilliant Procyon, the Lesser Dog Star. Now above, and to the left, are Castor and Pollux.

January 24-25. 7:50 to 8:50 P.M. (bottom of map at east). Below the still-brilliant moon, just above the horizon in the constellation of Leo, observers will find the first magnitude star, Regulus, shining rather faintly.

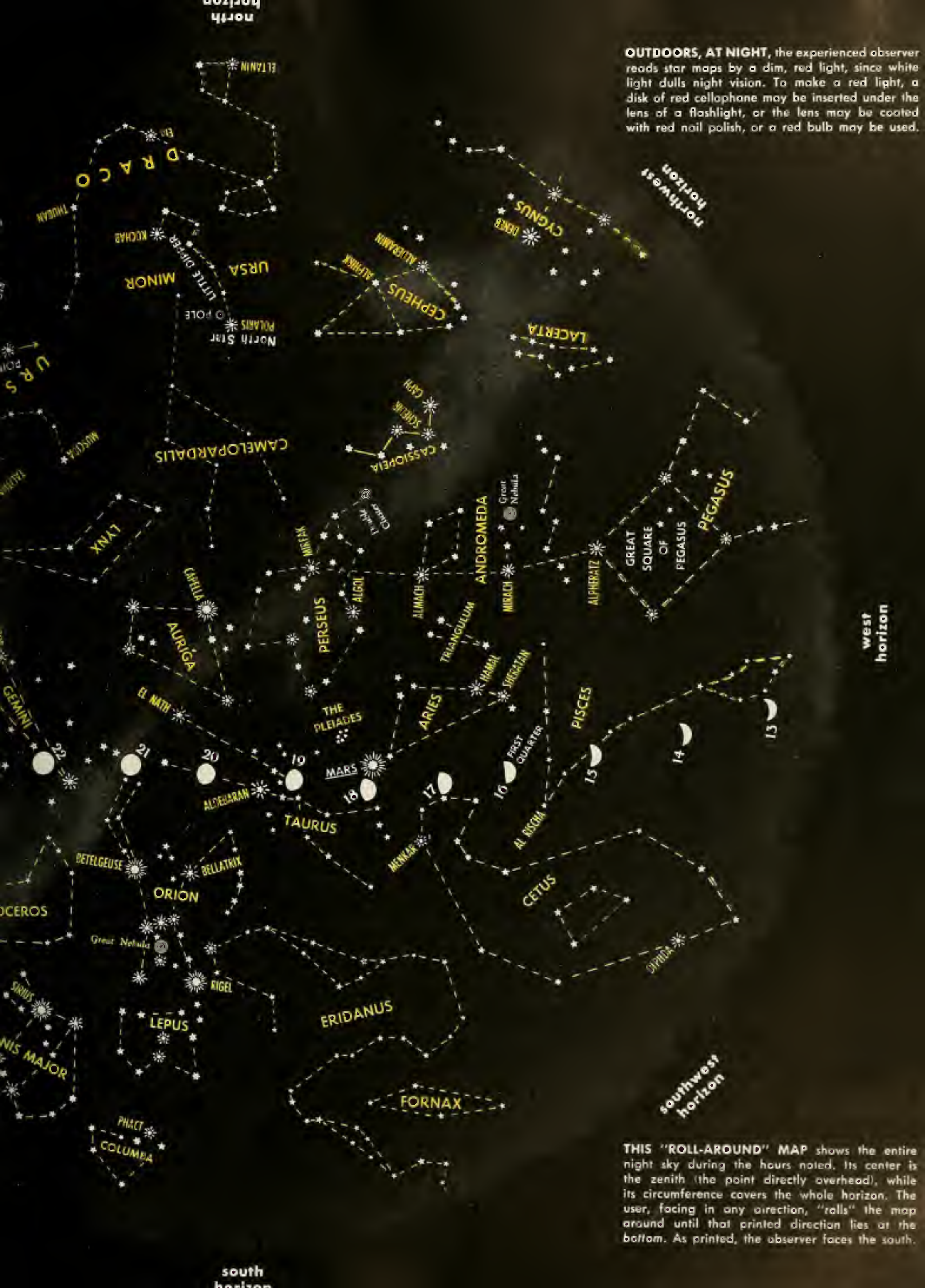
THE MOON'S PHASES

Last Quarter	January 2
New Moon	January 9
First Quarter	January 16
Full Moon	January 24
Last Quarter	January 31



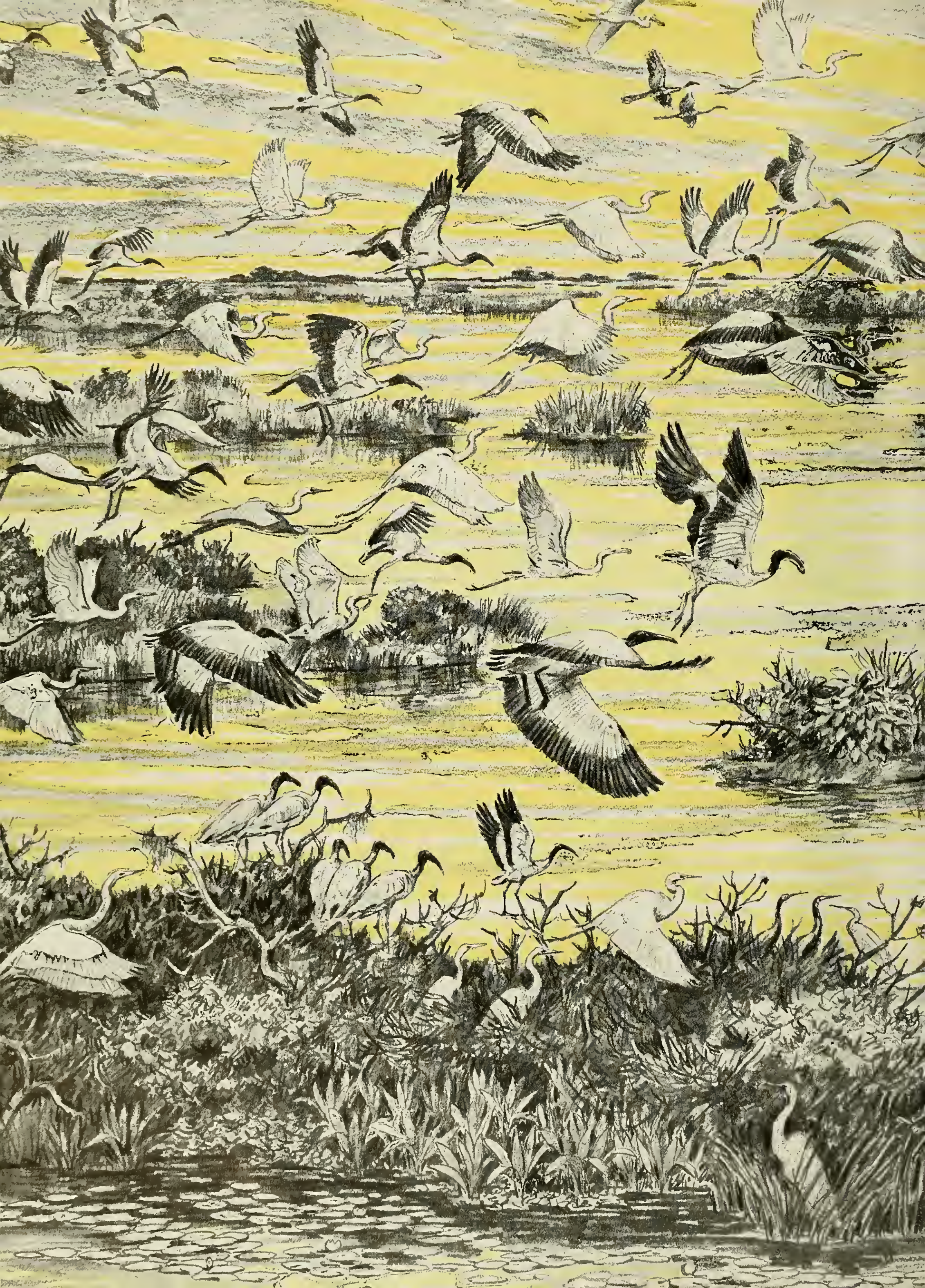
JANUARY TIMETABLE

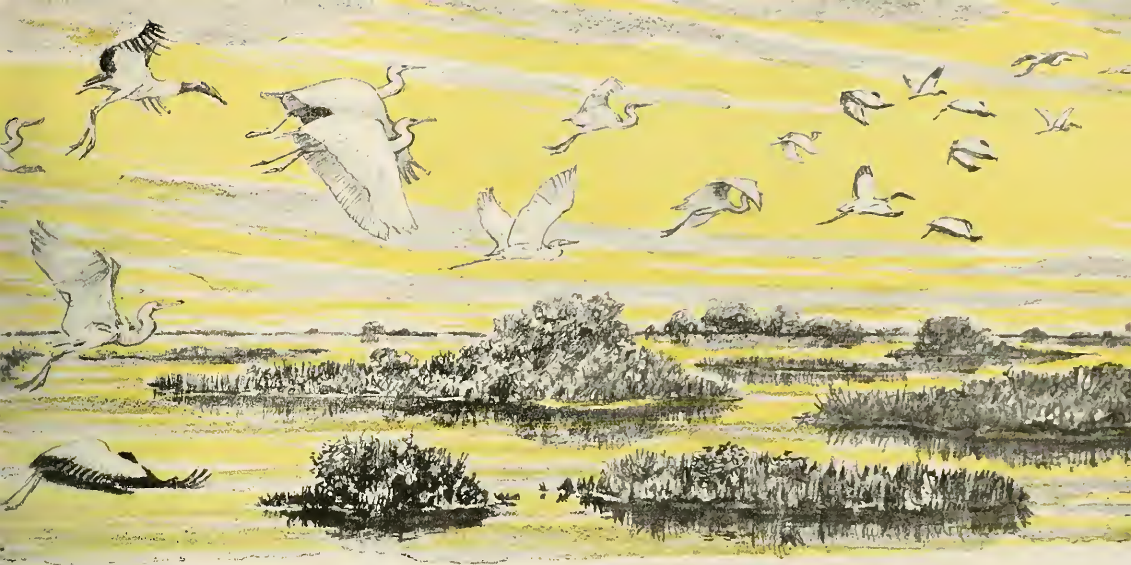
First week	9:30 to 10:30 P.M.
Second week	9:00 to 10:00 P.M.
Third week	8:30 to 9:30 P.M.
Fourth week	8:00 to 9:00 P.M.
Last week	7:30 to 8:30 P.M.


north horizon
ELTANIN
DRACO
THUBAN
KOCHAB
URSA MINOR
LITTLE DIPPER
POLE
POLARIS
North Star
CEPHEUS
ALDERAMIN
ALFIRK
CYGNUS
DENEB
northwest horizon
LACERTA
CAPH
SCHEDIR
CASSIOPEIA
CAMELOPARDALIS
LYNX
Double Cluster
Great Nebula
ANDROMEDA
MIRFAK
PERSEUS
ALGOL
ALMACH
MIRACH
ALPHERATZ
GREAT SQUARE OF PEGASUS
PEGASUS
west horizon
CAPELLA
AURIGA
TRIANGULUM
HAMAL
SHERATAN
ARIES
PISCES
EL NATH
GEMINI
THE PLEIADES
MARS
FIRST QUARTER
13
14
15
16
17
18
19
20
21
22
ALDEBARAN
TAURUS
AL RISCHA
MENKAR
BETELGEUSE
BELLATRIX
ORION
CETUS
Great Nebula
RIGEL
SIRIUS
LEPUS
ERIDANUS
DIPHDA
FORNAX
PHACT
COLUMBA
southwest horizon
south horizon

OUTDOORS, AT NIGHT, the experienced observer reads star maps by a dim, red light, since white light dulls night vision. To make a red light, a disk of red cellophane may be inserted under the lens of a flashlight, or the lens may be coated with red nail polish, or a red bulb may be used.

THIS "ROLL-AROUND" MAP shows the entire night sky during the hours noted. Its center is the zenith (the point directly overhead), while its circumference covers the whole horizon. The user, facing in any direction, "rolls" the map around until that printed direction lies at the *bottom*. As printed, the observer faces the south.





Floating Islands

In parts of Florida, these anomalies support a wide range of life

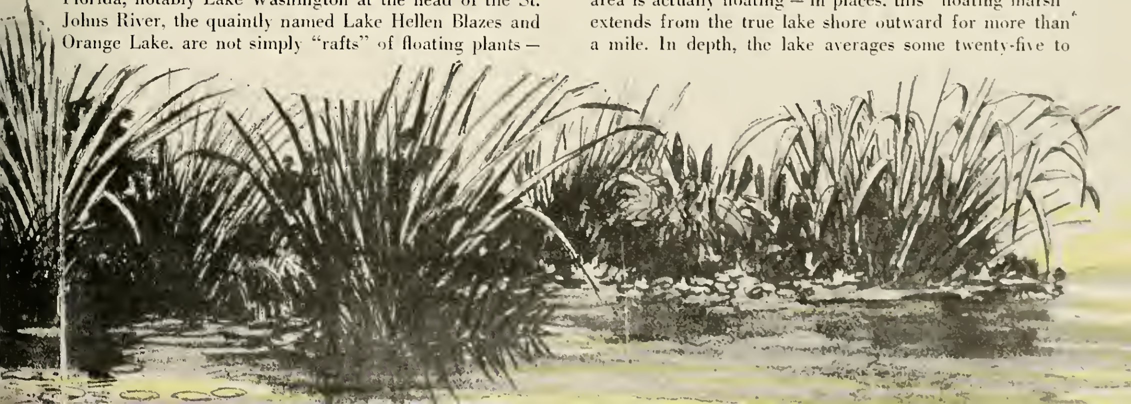
By George K. Reid

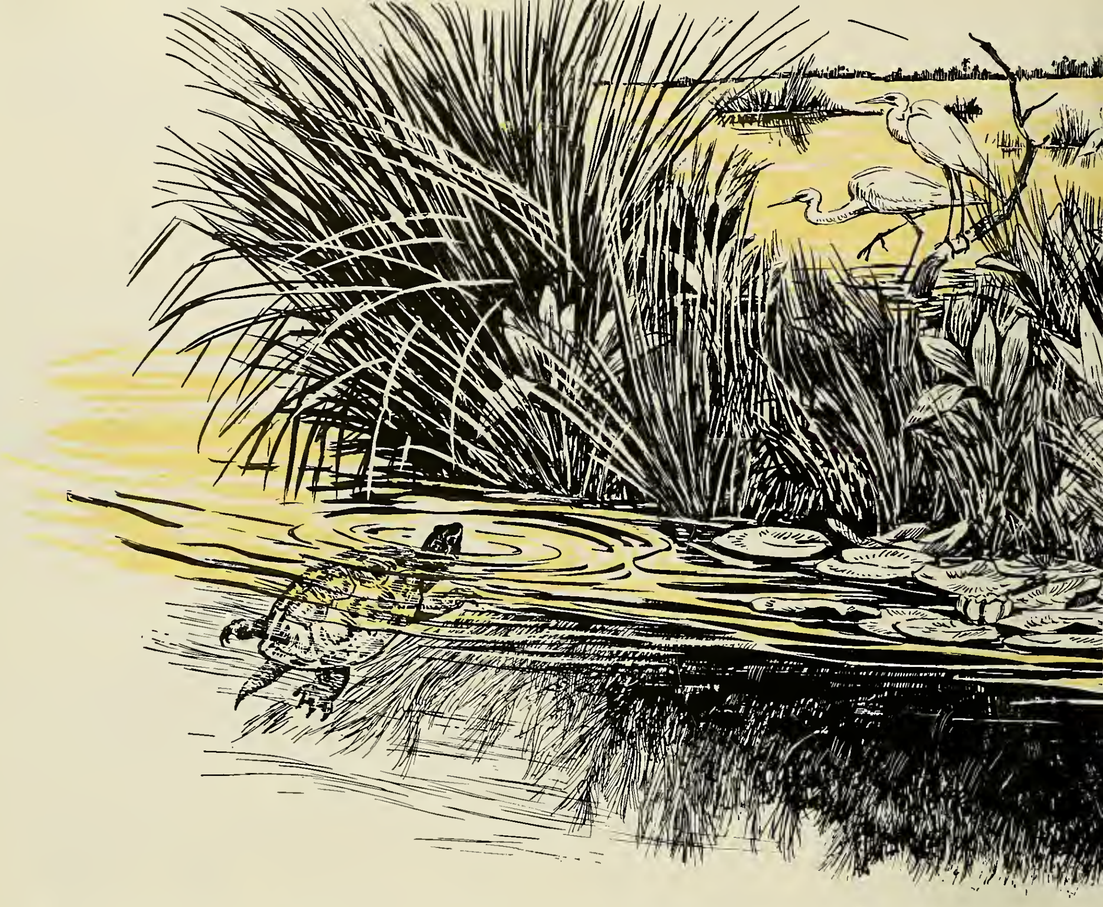
OVER THE YEARS, the poetry, legends and annals of many lands have told of floating islands. Among the early natural historians, both Pliny the Elder and Pliny the Younger have left us records of the occurrence of such islands. The elder Pliny cited several instances: ". . . the islands in Lydia, named the Reed Islands, [which] are not only driven by the winds, but can be punted in any direction at pleasure with poles, and so served to rescue a number of the citizens in the Mithridatic war."

Later accounts have described Old World floating islands – in England, Germany and Estonia – as well as New World ones – in Chile, in the bog lakes of Minnesota, in Lake Ontario and in the lakes of Florida. With the latter group I have some personal familiarity.

The floating islands characteristic of certain lakes in Florida, notably Lake Washington at the head of the St. Johns River, the quaintly named Lake Hellen Blazes and Orange Lake, are not simply "rafts" of floating plants – such as the intergrown masses of water hyacinths found in many lakes and streams of Gulf Coast states. Instead, they may be called "true" floating islands, consisting of a rather dense underlying layer, or substratum, of intertwined and tangled living roots, often intermeshed in a matrix of peatlike plant detritus. The plants, the roots of which are intertwined in the wet substratum, are diverse.

In describing the floating islands of Orange Lake, which I know best, it seems appropriate first to present some of the major features of this locality. Orange Lake, the largest of the several lakes in north central Florida, is a tributary of the St. Johns River. The lake's open water area is some 14,000 acres in extent. This open water is surrounded by marsh, dominated by spatterdock (*Nymphaea macrophylla*). Much of the apparent marsh area is actually floating – in places, this "floating marsh" extends from the true lake shore outward for more than a mile. In depth, the lake averages some twenty-five to





thirty feet, although a few sinkholes in the underlying limestone make the bottom in these areas deeper.

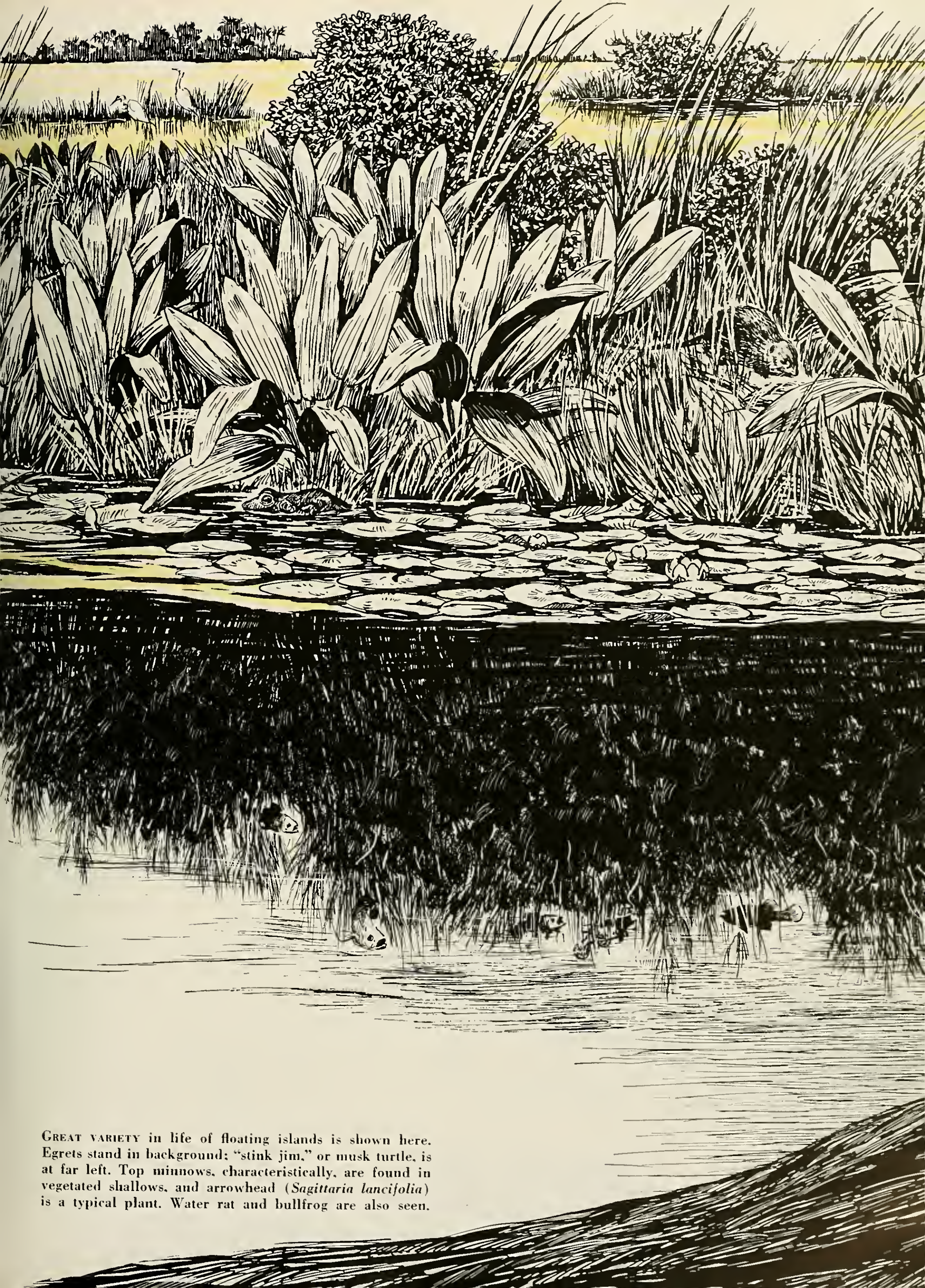
Such sinkholes, dissolved out of the underlying porous and soluble limestone, are commonplace in central Florida. Many sinkholes connect to subsurface water sources which may be important in maintaining a lake's level. Others may, instead, drain water away and — when surface runoff into the lake is deficient — will materially lower the lake's level. For example, flow measurements taken at Orange Lake, during October, 1957, revealed that lake water was being discharged into one sink at a minimum rate of two and a half-million gallons a day.

The combination of large amounts of suspended detritus, and of plankton organisms (and their extractives), causes the water of Orange Lake to be brownish or greenish in tint. The lake's bottom is sandy clay and limestone, covered by thick layers of silt and plant debris — derived mostly from within the lake. Submerged vegetation is scarce. Lake water, generally, may range from strongly acid to alkaline; Orange Lake is nearly neutral.

The floating islands of Orange Lake are impressive. They vary in size from minuscule mats of a few square feet, supporting a meager stand of small plants, to broad expanses of several acres, with an abundant cover of aquatic and semiaquatic shrubs and, even, low trees. To speak in botanical terms, these floating islands show no uniformity of species dominance or association of plants.

Pickerel weed (*Pontederia lanceolata*) and arrowhead (*Sagittaria lancifolia*) appear to be the most characteristic forms, although saw grass (*Mariscus jamaicensis*), smartweed (*Persicaria*) and spatterdock are frequently the most abundant. Among the trees, elder (*Sambucus simpsonii*), willow (*Salix*) and myrtle (*Myrica cerifera*) are conspicuous components of the plant community on some of the islands. A rich flora — consisting of such plants as pennywort (*Hydrocotyle umbellata*), parrot's feather (*Myriophyllum proserpinacoides*), duckweed (*Lemna minor*) or mosquito fern (*Azolla caroliniana*) — is usually present as a lower stratum. During the summer, many of the floating islands are bright with the yellow flowers of golden glow (*Bidens*), the white of arrowhead and spider lily (*Hymenocallis*) and the purple of the ubiquitous water hyacinth (*Eichornia crassipes.*)

The animal life of Orange Lake's floating islands, and the surrounding marsh in general, is as varied and proportionately abundant as is the plant life. This is not surprising in view of the considerable cover, food and microhabitats afforded by the islands' plant communities, their substratum and their "shore line." A number of



Great variety in life of floating islands is shown here. Egrets stand in background; "stink jim," or musk turtle, is at far left. Top minnows, characteristically, are found in vegetated shallows, and arrowhead (*Sagittaria lancifolia*) is a typical plant. Water rat and bullfrog are also seen.

A native Southerner who, as a student at the University of Florida, studied the fishes of Orange Lake intensively, Dr. Reid is now Assistant Professor of Zoology at Rutgers.

mammals are quite at home both on the islands and in the adjoining marsh. An especially common inhabitant is the raccoon, which is often seen swimming from island to island, questing for food. The marsh rabbit (*Sylvilagus palustris*) is found, and the water rat (*Neofiber alleni*) is known to frequent both the marsh and the islands.

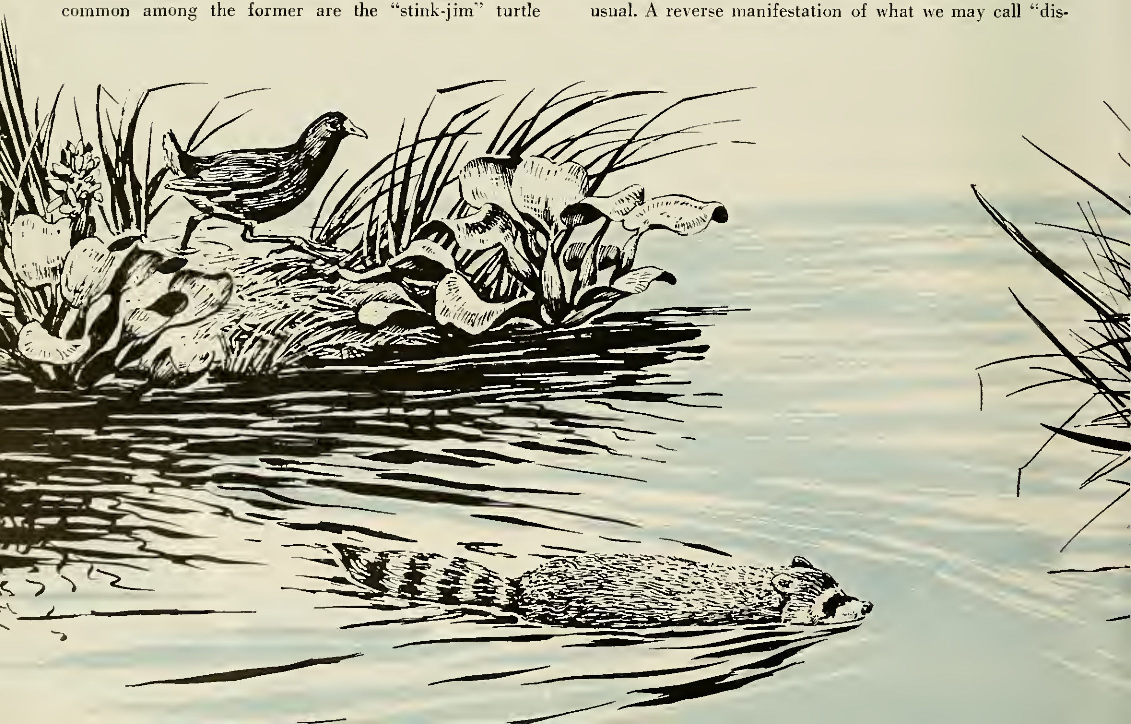
As a whole, Orange Lake is also the habitat for a variety of birds, many of them in great numbers, that evidently find adequate food and nesting sites on the islands and marshes. Since the turn of the century, Bird Island — with an area of nearly three acres — has been recognized for its remarkable avian population: the evening flights of ibises and egrets onto this rookery are a widely known spectacle. Other characteristic breeding birds often associated with the floating islands include herons, gallinules, red-winged blackbirds, grackles and the so-called "water turkeys" (*Anhinga*). Coots and grebes are also common in the area and, in winter, migratory ducks add new life to the scene.

Nor is this all. Amphibians and reptiles are conspicuous members of the island's animal communities. Of the amphibians, the newt and the striped mud eel live among the submerged roots of the plants and along the islands' edges. Of the tree frog family, the cricket frogs (*Acris gryllus*), green tree frogs (*Hyla cinerea*) and squirrel tree frogs (*Hyla squirella*) are common — their voices contribute to the thrilling din that follows a spring rain. Bullfrogs, such as *Rana grylio* and *Rana pipiens*, also occur in varying numbers. Turtles and snakes possess an ecological association with these floating islands. More common among the former are the "stink-jim" turtle (*Sternotherus odoratus*), frequently seen nosing around submerged roots, and the "cooter" (*Pseudemys floridana*), which suns itself on logs and edges of islands. On the islands' surfaces, the green water snake (*Natrix cyclopion*) and the banded water snake (*Natrix sipedon*) are typical, while the burrowers — the striped swamp snake (*Liodytes alleni*) and others such as *Farancia* and *Seminatrix*—inhabit the substrate.

Both the lush emergent vegetation and the submerged roots of the floating islands' plants support prodigious numbers of another animal category — the invertebrates. Among the insects, the aquatic bugs (Hemiptera) and beetles (Coleoptera) thrive on and in the shallow shore zones. Seasonally, the midges, or dipterans, emerge in vast droves. Studies of the food of lake fish reveal the nymphs of twelve species of dragonflies; a large proportion of these inhabit the islands. In our insect inventory, one species of ant (*Tetramorium guineese*) appears to be a typical inhabitant of the emergent vegetation here.

Other invertebrate inhabitants include the spider (*Dolomedes*)—abundant and known to feed on small fishes in this area. Crustaceans such as the amphipod (*Hyalella azteca*) and fresh-water shrimp (*Palaemonetes paludosus*) are sufficiently common in the submerged portions of the marsh and the floating islands to constitute major food items for the lake's young and adult fishes.

In this connection, of the thirty-five or so species of fishes known to inhabit Orange Lake, several exhibit interesting and close relationships with the floating islands. Top minnows (*Gambusia affinis*) and least killifish (*Heterandria formosa*) are typically inhabitants of vegetated shallow waters in small streams, ditches or lake and pond shore zones. In Orange Lake, these two fishes have become associated with the margins of floating islands; in this habitat, they are found some distance from shore, the depth of water beneath them many times greater than usual. A reverse manifestation of what we may call "dis-

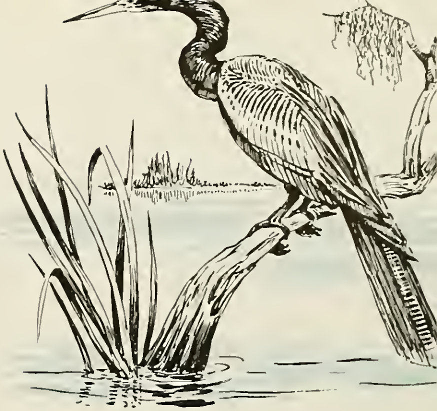


placed habitat" is shown by the darter (*Etheostoma barratti*), normally a bottom dweller, that is to be found among the tangled roots of floating islands, many feet above the lake's true bottom. It is, of course, obvious that — to these fishes — the edges of the islands serve simply as a "home away from home"; or, more properly, that the floating island habitat satisfies the fishes' ecological requirements and thus represents no great change.

The prime questions in the case of floating islands are: how are they formed; and how do they float? In Orange Lake there appear to be two ways in which the floating islands can be formed. Much of the marsh surrounding the lake, as we noted earlier, is floating. As the rooted plants extend their growth from the lake shore outward, their roots intertwine and the increased buoyancy offered by the resulting air spaces causes the root mat to rise. Floating, lakeward portions of this marsh growth may become detached by wind and wave action. In this case, an island — already equipped with plant and animal communities — would be set free to drift.

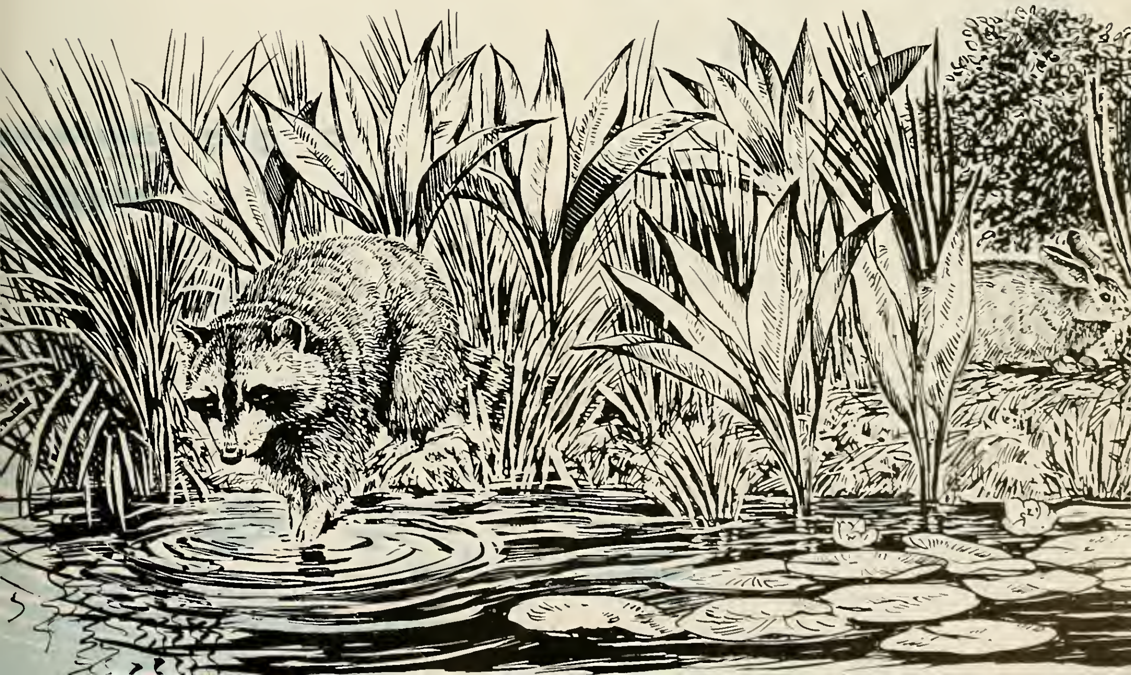
The second mechanism of formation is more spectacular: compact masses of lake bottom detritus have actually been observed to rise to the water's surface. Such emergent islands are, of course, bare of most life forms, and are later invaded by the plants and animals we have described.

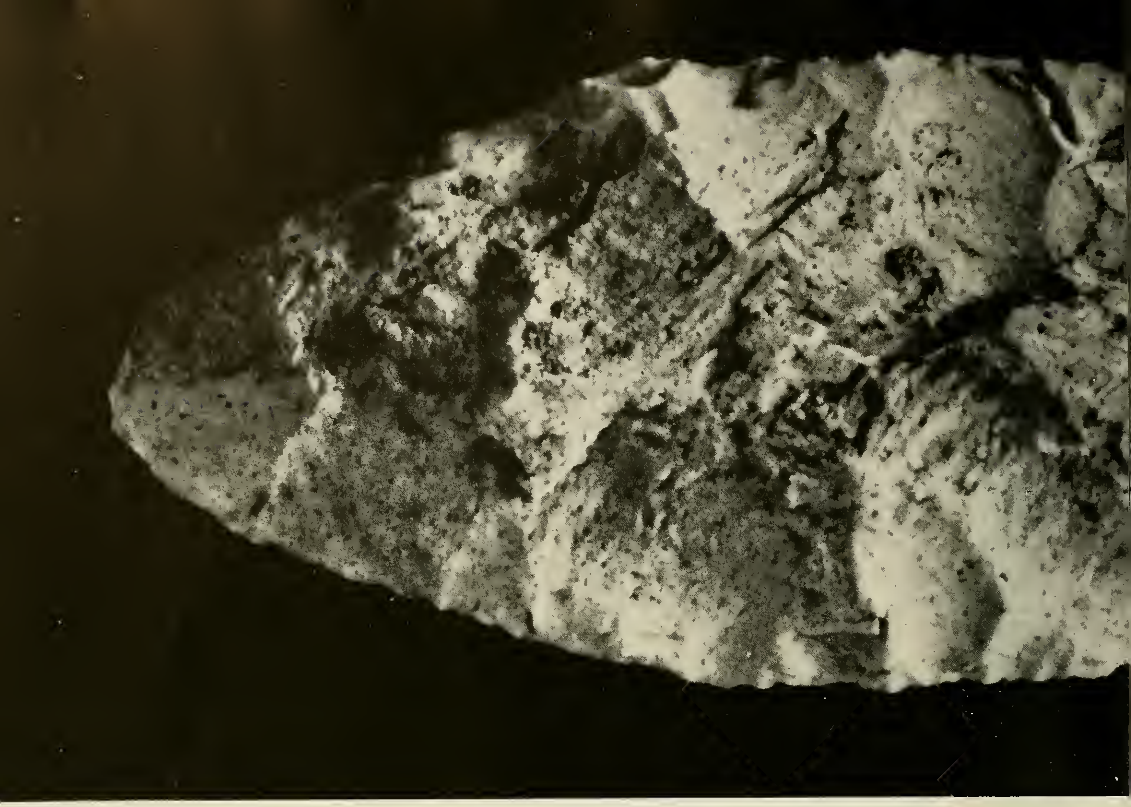
The very birth of this second class of floating islands brings us to the next question — the matter of buoyancy. What keeps the islands afloat? At least two explanations seem plausible; there may be others as well. Those mats which rise from the bottom of the lake are probably buoyed up by gases of decomposition. As long ago as the early 1800's, the great English chemist Dalton analyzed the gas in the material composing floating islands in his native Lake District. Dalton found methane ("marsh gas") and nitrogen, in equal amounts, to a total of 90 to 95 per cent, with an additional 5 to 10 per cent of carbon dioxide. Once such a mat is floating, its buoyancy is doubtless increased by a second factor. The air chambers in the roots of some of the living hydrophytes that invade the islands — the root mass of saw grass in particular — are quite buoyant. It seems only proper to say, however, that a *completely* satisfactory explanation of the flotation mechanism of these islands is still forthcoming.



The eventual fate of many of Orange Lake's floating islands is to become incorporated into the fringing marsh. For some of the islands, this is a return to origin: for others, a new resting place. In either case, the islands continue to contribute to the productivity of the marsh and the abundance of plant and animal life we have observed. Even the islands that have been known to sink, not rise, cannot but add something to the rich biological bouillabaisse that constitutes this remarkable Florida lake.

"Water Turkey," drawn *above*, is a typical breeding bird of floating islands. *Below*, *l. to r.*, are a gallinule, raccoons and a marsh rabbit. The large plants are water hyacinth (*l.*) and pickerel weed (*r.*), with spatterdock in the foreground.





PART I

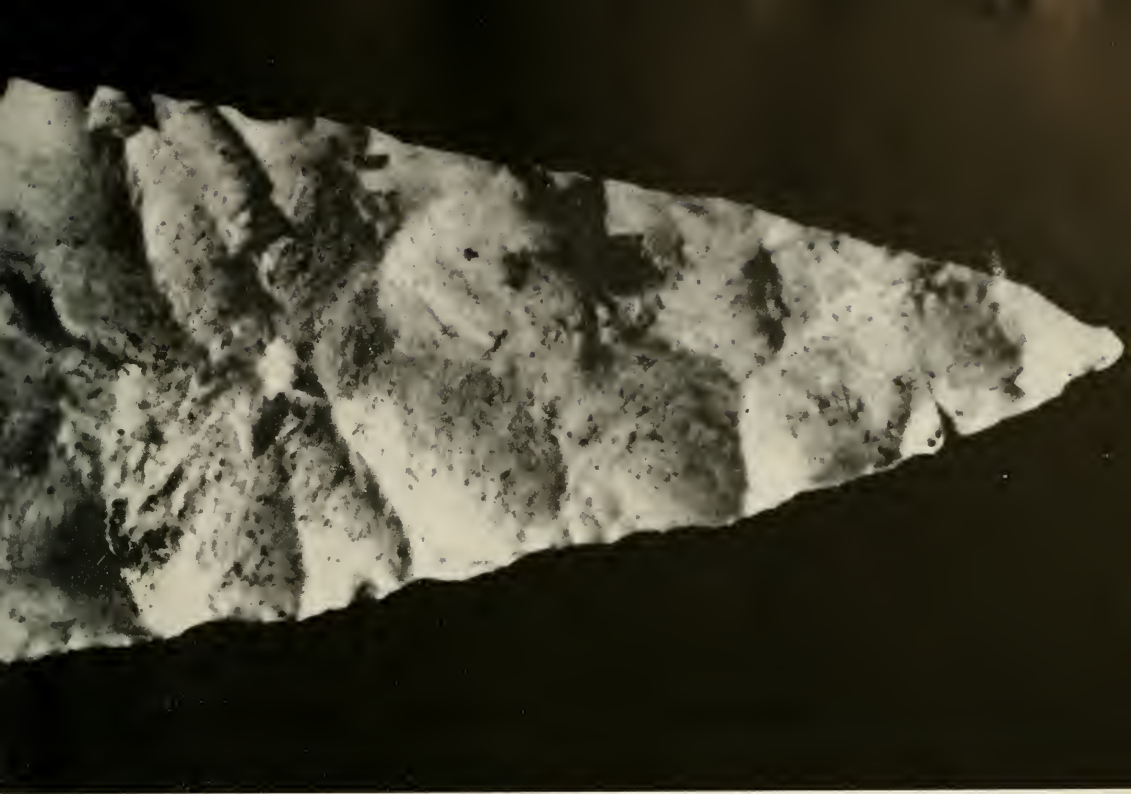
First Tools of Mankind

STONE IMPLEMENTS RECORD HALF A MILLION YEARS OF TECHNOLOGICAL PROGRESS

By JACQUES BORDAZ

Illustrated by LEE BOLTIN and JEAN ZALLINGER

IT IS HARD TO REALIZE today that only two centuries ago both the origin and nature of the objects to be presented on these pages were totally misunderstood. Mankind's long use of metal had virtually obliterated the memory of stone as a material for the manufacture of tools and weapons: the hand axes and other surviving implements of the Paleolithic period were then believed, instead, to be works of nature. Over most of the Old World, indeed, they were usually referred to as "thunderstones" or "thunderbolts," in the belief that they represented the end product of a lightning stroke. In certain parts of Scandinavia and France, this belief was still held during the last century, and the *pierres de foudre* were hopefully placed in the walls or under the doorsills of farmhouses in an attempt to deceive lightning, which, as was well known, never struck twice in the same place. Nor was this mere peasant superstition: early scholars called these stones "ceraunias" (from the Greek *keraunos*, thunderbolt) and proposed the most complex explanations as to which proportions of humidity, solar and stellar radiation and lightning had produced the strange objects. Since so many apparently reliable observers had stated for centuries that they had found ceraunias at the very place where lightning had struck, little attention was given to a seventeenth century mineralogist, Boece de Boot, who suggested that—in view of the unique

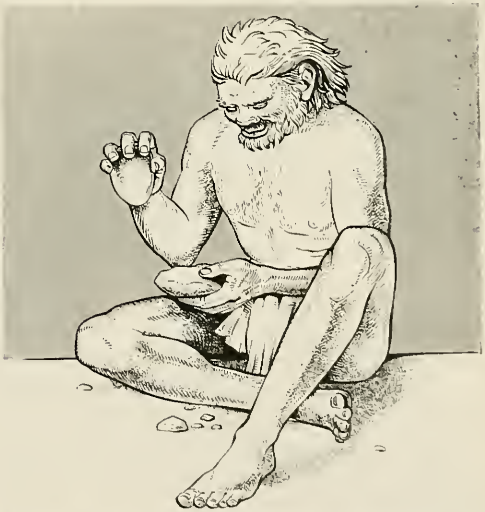


Height of craftsmanship among paleolithic workers in flint is the Solutrean "laurel leaf" blade, *above.* Finest specimen known is over a foot long, a quarter-inch thick.

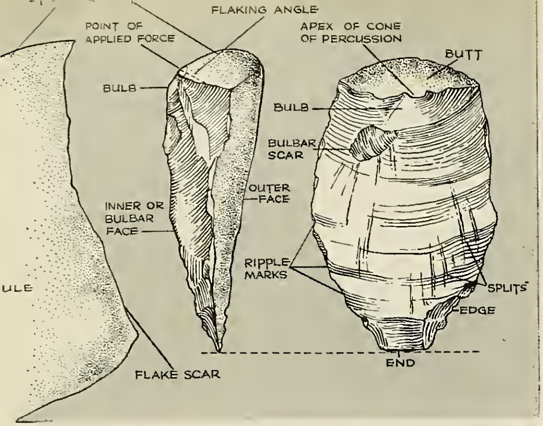
form of the ceraunias—they might have been iron implements which had turned into stone through the ages.

It was not until 1723—as a late-ripening fruit of the Age of Exploration—that the "thunderstone" belief was vanquished by scientific evidence of the true nature of these stone objects. The naturalist Antoine de Jussieu, in a memoir entitled *De l'Origine et Des Usages Des Pierres à Foudre,* pointed out that some stone objects from the West Indies and Canada, which were known to have been manufactured and used by the aborigines of these regions as tools and weapons, were very similar to the European ceraunias, and that it was probable that the early inhabitants of Europe had also manufactured tools and weapons of stone. Still, it required more than another hundred and fifty years—until the end of the nineteenth century—before the period called by prehistorians the "Stone Age" was recognized to represent a vast span of time in man's history: a period now estimated to have lasted perhaps more than a hundred times longer than the five thousand years that have passed since the invention of metallurgy in the Near East.

Of all the activities of man during these distant millennia that are known to us today, the closest to us—that is, the most easily appreciated—are the many cave paintings of the Paleolithic, found in southwestern



Making a core tool, this paleolithic knapper holds the flint nodule in his left hand, and shapes its cutting edge with a series of blows from the hammerstone in right hand.



Typical flint flake is shown, *above*, in profile and back view, beside the nodule from which it was split. The legend gives the principal terms of knapping nomenclature.

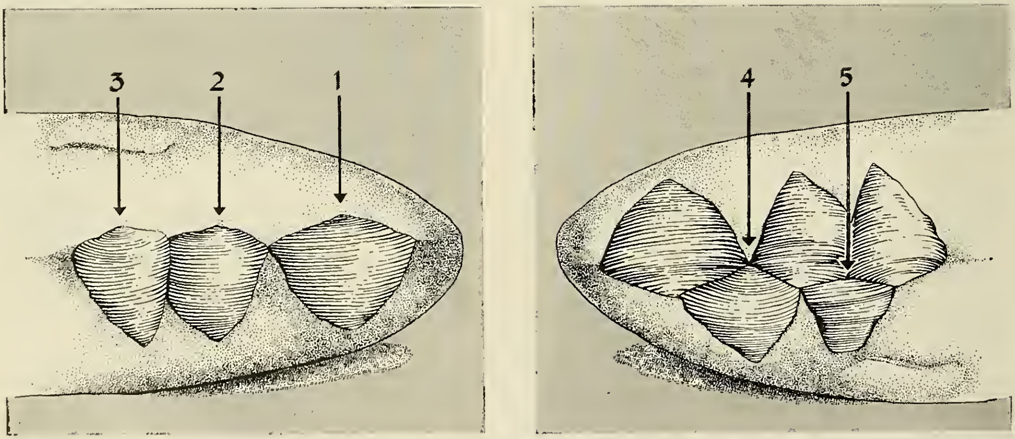
Europe. Their magnificence, boldness and beauty, the esthetic emotions these works evoke in us, all seem to erase the enormities of intervening time. Prehistoric stone implements also possess a beauty, although their beauty is of another kind. Admirably adapted to their purpose, they cannot but please those able to appreciate the elegance of these tools in their solution of the relationship between form and function. Many of these implements demonstrate form, texture and workmanship that transcend their prosaic uses.

The major concern of scholars specializing in prehistoric stone implements has been with typological studies; that is, the analysis of recurrent forms, which—in conjunction with geochronological evidence—leads to temporal and regional classifications of the ancient human societies that produced these tools. In contrast, the purpose of this study is technological, rather than historical: we wish to learn what we can about the uses to which these tools may have been put, and the ways in which they were produced. In consequence, most of our examples have been taken from the area which—at least, today—is richest in this material: western Europe, and France in particular.

By way of preface, some of the terms which prehistorians use should be defined. The division of prehistory into three periods—the Paleolithic ("old stone"), Mesolithic ("middle stone") and Neolithic ("new stone") periods—is essentially a technological one, based on the manner in which stone implements were shaped. Thus, in the Paleolithic, stone was shaped exclusively by *flaking*. In France, the area where all of the implements here illustrated were made, the Paleolithic coincides with the glacial period. The Mesolithic, in this same area, was a transitional era, in immediately postglacial times. During the Neolithic, the most recent period, stone tools usually were shaped by *grinding*, rather than flaking. The final period lasted in Europe until some four thousand years ago, when copper and bronze were introduced.

It is evident that stone was not the *only* material used by man during the "age of stone." In a few early sites, parts of wooden spears have been found; and in rock shelters—where preservation is better than in open sites—a great number of bone and antler objects have been discovered. The fact that stone is practically indestructible (and hence that stone implements constitute the majority of finds) is *not* the primary reason for the use, here, of this prehistoric nomenclature. Rather, it is in recognition of the fact that the stone tools were the most important part of the equipment of early man. For they alone provided him with the working edge and the point he needed for cutting, chopping, scraping, piercing and shaping the now largely vanished materials—such as wood, bone, antler, sinew and skin—which comprised the remainder—and possibly the major—part of his material culture.

For hundreds of thousands of years during glacial and early postglacial times, man successfully survived, first as a hunter and later (from about six thousand years ago



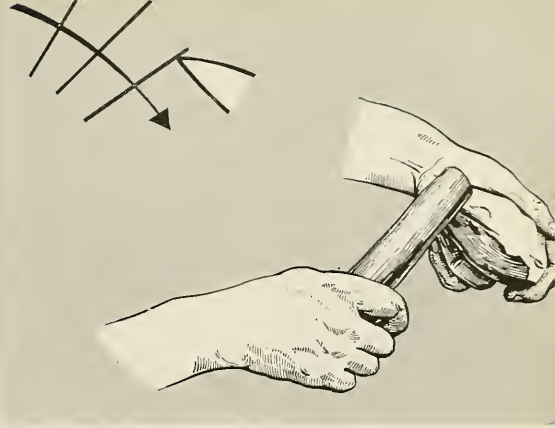
Earliest bifaces, produced by the Abbevillian technique, had a sequence of sharp blows (1 through 3, *above*) struck near natural edge of nodule, detaching flakes from under face. Nodule was then turned over, and next blows (4 and 5, *above*) were struck on ridges formed by adjacent scars of first knapping. Result: a wavy, but strong working edge.

in Europe) as a food-producer and husbandman. During all this time, stone was his principal means of exploiting nature, and man's progress in this exploitation was associated with technological advances in stone implements. These advances show themselves in two main ways. First, there was an evolution in the forms of the implements—which were developing from generalized, all-purpose tools and weapons to more specialized and better-adapted ones. Second, there was an evolution in the mode of their manufacture. Man was learning to make better use of suitable raw material: he not only reduced waste but also developed new techniques which enabled him to utilize a greater variety of materials for the manufacture of his stone weapons and tools.

What were the shapes of the earliest stone implements? It is inevitable that, endowed with a prehensile hand, the earliest man must have picked up and used ready-made tools, such as sticks, bones and pebbles, which in some cases had a naturally broken cutting edge. Smashing stones and selecting those fragments with useful cutting edges would have been a logical first step in tool-making, but we cannot expect to find evidence of this "first" tool manufacture, for such haphazardly flaked stones are indistinguishable from those flaked by nature.

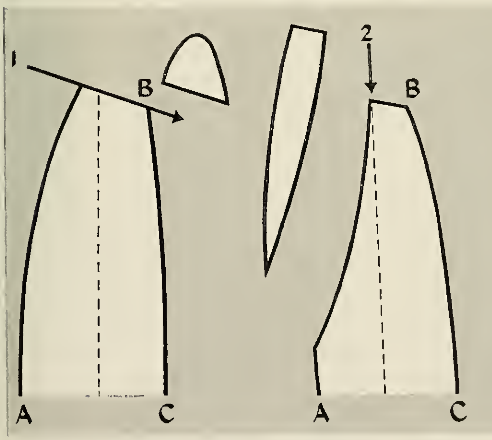
However, archeologists have recovered from geological strata in South Africa—equated with late Villafranchian strata of Europe—collections of flaked stone that must be very close to the beginning of systematic stone-working. Estimates of the age of the Villafranchian vary from 1,000,000 to perhaps only 300,000 years ago, the latter date being that of the "short chronology" recently calculated by G. Emiliani, which cuts current age estimates approximately in half. These South African artifacts demonstrate, in contrast to naturally flaked stone, a certain uniformity of shape and direction of flaking, indicating deliberate design.

Flint, when available, has always been a favorite European tool material, for it has all the necessary qualities found to varying degrees in the other siliceous stones—chert, quartzites and the like. Besides being very hard (it will scratch most steels), flint is also homogeneous. Because flint has no natural planes of cleavage, a force applied at one point on its surface radiates symmetrically within the material, and breaks the stone along a plane of segmentation whose position can theoretically be controlled, within limits, by manipulative skill alone. For example, both the angle of impact and the degree of force may be varied. The forces radiating from a point of impact at the center of a piece of such homogeneous material will theoretically punch out a cone, leaving a slightly rippled, conical scar. If the point of impact is near the edge, a chip will flake off—leaving a rippled half-cone scar similar to those seen on the edge of chipped glass. The illustration (*top, left*) shows a flint flake detached from parent material and its characteristic features.

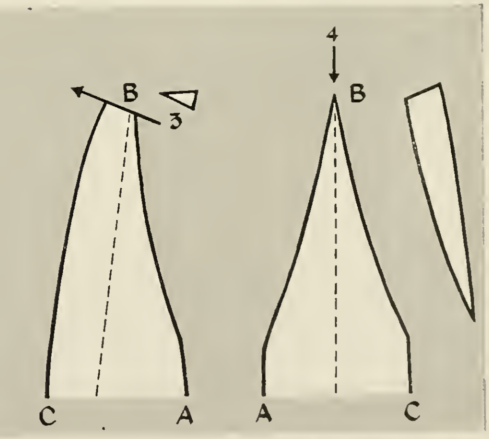


A major advance in biface manufacture was the Acheulian technique of detaching long, shallow flakes with blows of a "baton," *above*, striking directly against the tool's edge.

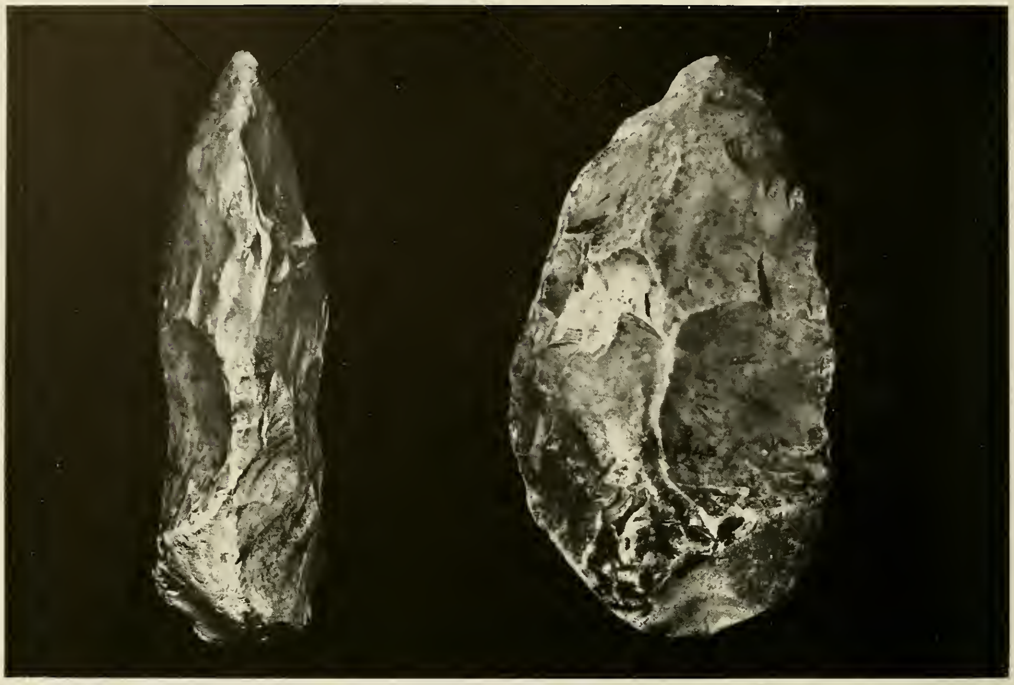
How can flint, and allied siliceous rocks, best be



Preparation of "platform," which permitted control of flaking, is diagrammed, *above*. First, *left*, a part of the nodule's natural edge was struck off, leaving a flat area.



Next blow detached a long, shallow flake. Then, *above*, a third blow prepared another "platform," and a fourth blow removed a matching, shallow flake from the opposite side.

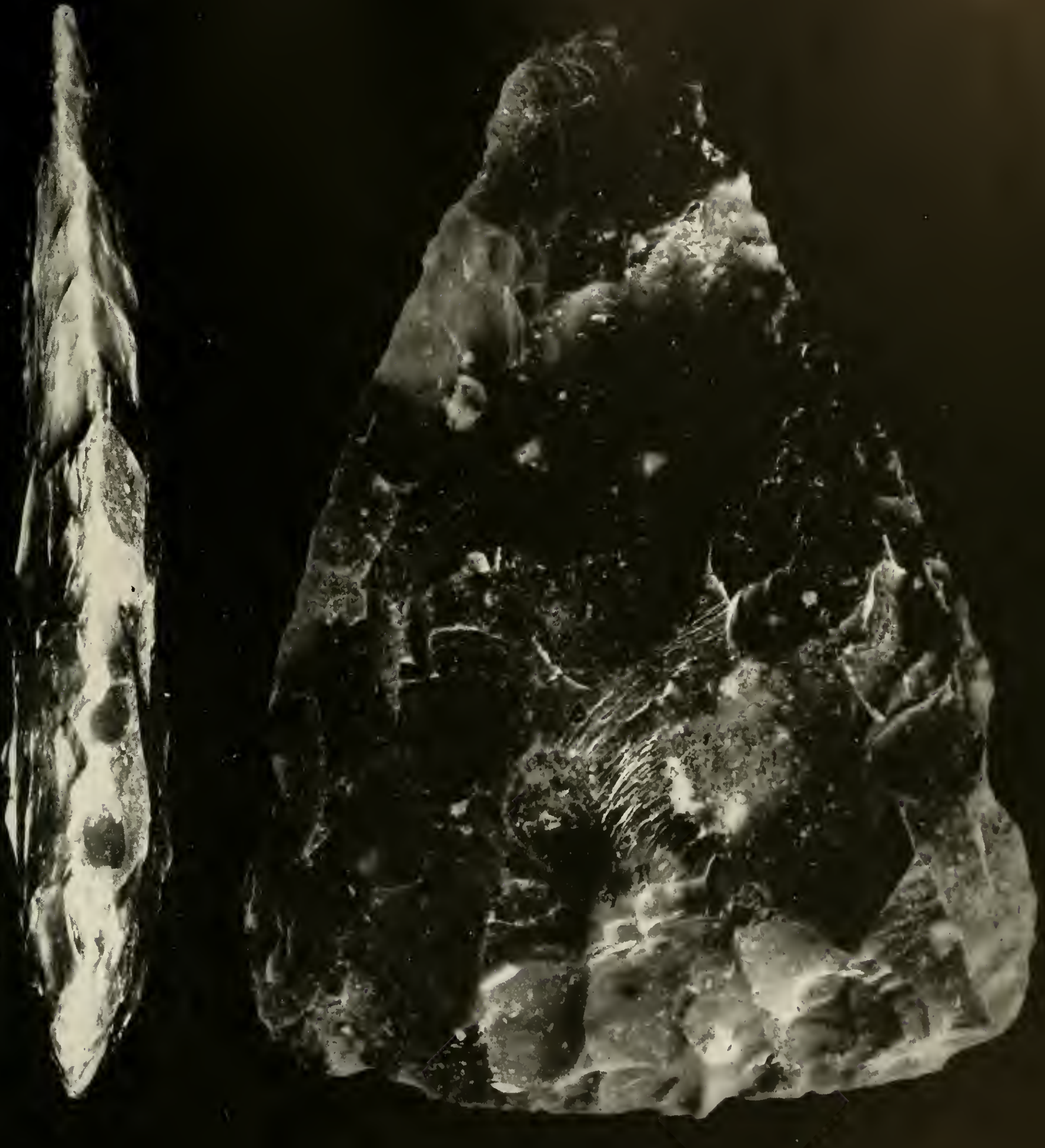


Early core tool, seen both edge-on, *left*, and broadside, *right*, is a biface that was made by means of Abbevillian techniques. Sinuous working edge and deep flake scars are typical of these thick, roughly shaped implements, which apparently were used as all-purpose, cutting and chopping tools. This specimen is six inches long, and two inches thick.

worked? There are, essentially, two methods for obtaining implements with a useful working edge by means of flaking. The first is to strike the flint nodule against some projection of a heavy rock—used as an "anvil"—or, alternatively, to use a hard pebble, held in the hand, as a "hammer." The flakes of flint detached in this manner (in most cases referred to as Clactonian, from the name of the English type-site, Clacton-on-Sea), although usable, are generally clumsy and irregularly shaped. Clactonian flakes have a large cone of percussion and a prominent bulb, the latter leaving a deep bulbar depression on the flint's nucleus. These flakes may either be used as tools exactly as they come off the nucleus of flint, or improved by "retouching"—that is, by further flaking. In essence, the end product of this first system is the flake: the remaining nodule is a raw material reserve.

The second method, in contrast, is to remove flakes from the flint nucleus according to a predetermined design, with the aim of shaping the "core" into an implement. Such implements are called core tools, and the knapper—while he will save any usable flakes he produces—is not primarily interested in the flakes. His objective may be a single implement, with its cutting edge formed by the intersection of two opposite series of flaked scars; or the core tool may be formed by flaking part of the edge on one "face" only, leaving the other "face" unflaked. Since core tools tend to be massive, they are better suited to heavy work (such as chopping) than are the thinner, flake tools. Flaking a flint nodule on both faces to obtain a rough point (a form that prehistorians call hand axes, or bifaces) would seem to be an advance that derives naturally from the earliest of these core tools—which were usually flaked, on one or both faces, only along *part* of the edge. This technique of producing bifaces spread early over Africa and into Europe, where it seems to have first been used about two hundred thousand years ago (again, according to the Emiliani "short chronology," used throughout this article).

Bifaces were usually pear-shaped, from five to six inches long, and were flaked over most of their border. They offered a strong picklike point, as well as a cutting edge, the thickness and curvature of which varied around the periphery of the implement, making it useful in a variety of tasks. Exactly how were they used? The evidence is against their being used as missile points: usually they were too bulky and, unless thinned at the base, could not have been securely attached to spears. Some might have been used as daggers, or wedged into the thick part of wooden clubs, but most of them appear to have been all-purpose tools for cutting and chopping. Some were so flaked that the small area which pressed against the palm of the hand was left unchipped: in other cases, the user's palm probably was protected either by a pad of skin, a mass of resin or by bark. In general, we may assume that bifaces were used for all heavy chop-



LATER CORE TOOL shows advanced, Acheulian techniques: prepared striking platforms (which permitted the knapper to control implement's shape) and, frequently, use of the baton for chipping. Typical late Acheulian biface, *above*, has a thin cross section and straight edges. It is almost six inches long but only three-quarters of an inch thick.

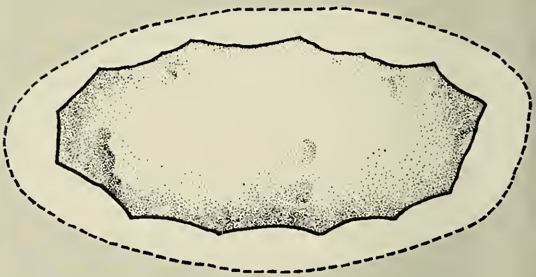
ping, scraping and cutting that could not have been done with the thinner, flake tools. Bifaces could also have been used for cutting and roughing-out wooden spears.

The stone age technologist progressively improved the effectiveness of the biface. The early types (called Abbevillian, after the type-site in France) had some serious defects due to the primitive technique used to flake them (illustration, *on p. 40*). When a nodule of flint is flaked by direct hammerstone or anvil technique, the resulting flakes are short and massive. Their bulbs of percussion leave deep scars, whose intersections form a wavy, inefficient cutting edge. Moreover, since the scars rarely carry very far across the face of the implement, part of the original surface of the nodule remains in the center of the tool, making the Abbevillian biface clumsy because of its thick section. It is possible, in some cases, to partially straighten the working edge by flaking away the marginal spurs formed by adjacent scars. But this does not give the tool the tapering section necessary for deep chopping or cutting. Modern experiments have shown that if blows are struck nearer to the flint's edge in an effort to extend the scars across the face the edge will frequently be crushed. To sum up, then, the Abbevillian toolmaker doubtless had a mental picture of the tool he wanted, but his technique was too primitive to allow him to control the shape of his implement in any but a general way. New techniques had to be developed: from them came the Acheulian biface—with its straight cutting edge, tapering section and two smooth faces.

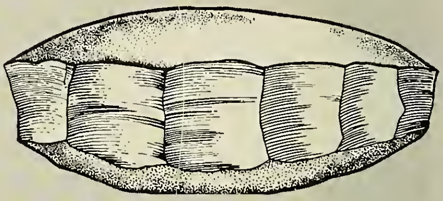
THE Acheulian knapper seems to have used two new techniques for production of his core tools. The first of these is a method of considerable importance, because it was used extensively—in later times—by more advanced makers of stone tools. It consists of flaking the edge itself, in order to build up preliminary striking platforms set at the correct angle (about perpendicular) to the face to be flaked (*see p. 39, bottom*). The flakes struck from these prepared platforms leave scars carrying back across the face of the implement, resulting in a tool with the desired thinner, more tapered section. Now, the preparation of a striking platform, preliminary to flaking, greatly increased the knapper's degree of control over the shape of his bifaces. But most modern experimenters believe that the very shallow flake scars, with long parallel sides —observed on the finest of Acheulian bifaces—are possible to produce only by means of an additional trick of technique. This is the baton method (*see p. 39, top*).

As the name of this second method implies, it involves the use of a hard wood, bone or antler baton, which, because it is of softer material than stone, can be struck directly against the edge of the nodule without crushing it. The flakes resulting from such baton blows have a very diffuse bulb of percussion and are long and thin. The resulting scars are almost flat and form a very straight edge by intersection. It can be inferred, by analysis of such evidence, that the Acheulian bifaces were first roughed out by hammerstone percussion, with or without preliminary platforms, and then finished with a baton. The Acheulian biface (photo, *page 41*) clearly reveals the characteristic deep, rippled scar resulting from hammerstone percussion, together with the long, shallow scars characteristic of the baton technique. Some of the later Acheulian bifaces are the most perfect expressions of the

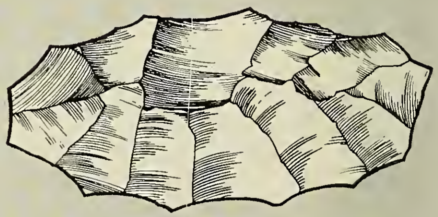
NEW METHOD



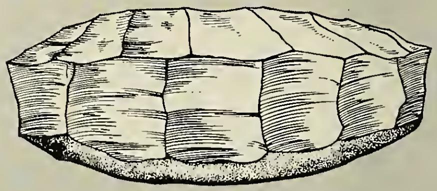
First step: trimming edges of nodule.



Side view of the edge-trimmed nucleus.



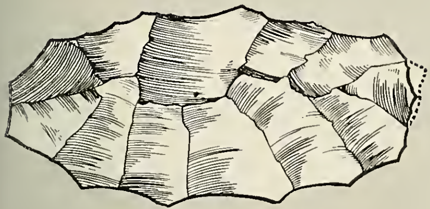
Next step: top surface is also trimmed.



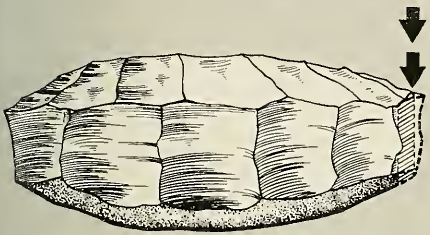
Side view of the fully-trimmed nucleus.

THE NEXT ADVANCE in flint technology was the Levalloisian technique (shown in steps, *above*). By preparing the flint nucleus in advance, a knapper was able to strike off large

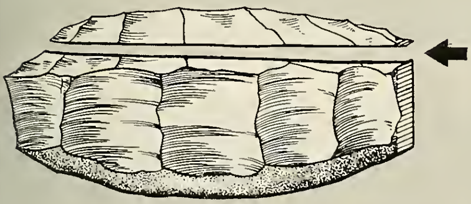
FOR FLAKES



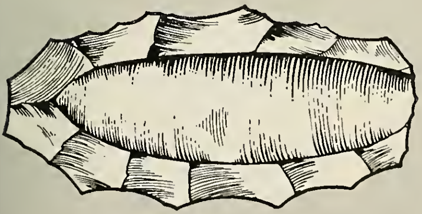
Third step: striking platform is made.



Side view of nucleus (platform, *right*).



Final step: flake struck from nucleus.



Top view of nucleus (flake is removed).

flakes of predetermined size and shape, which could then serve as implements. Easier to make than a biface, these tools had the advantage of the flake's smooth, sharp edges.

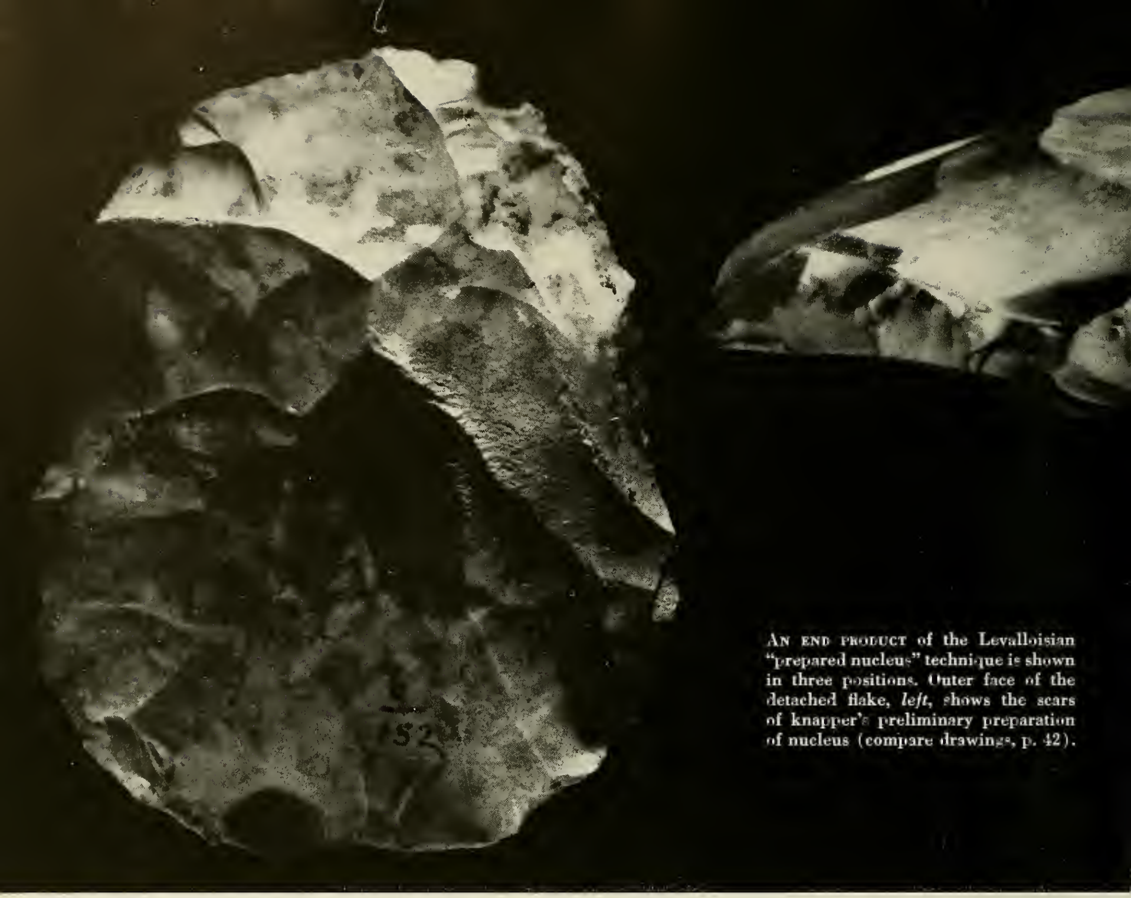
core-tool concept. Once the knapper had decided on the shape (usually pointed, ovate or cleaver-like) and size best suiting his purpose, he could, by using the platform and baton technique, produce symmetrically shaped bifaces tapering smoothly toward almost straight edges.

Although such predetermination of shape was not possible in making the *early* flake tools, flakes nonetheless have certain advantages over the bifaces. For one thing, their manufacture is not so wasteful of flint as the shaping of a biface—which requires the removal of a great deal of material from the flint core, with only a few usable flakes resulting. For another, a flake tool's cutting edge is obtained by a single blow on the flint nucleus, while the production of a similar thin, straight edge by alternate flaking of a biface requires a great deal of time and skill. Finally, the cutting edge of the best possible biface is never so sharp and smooth as that of a flake.

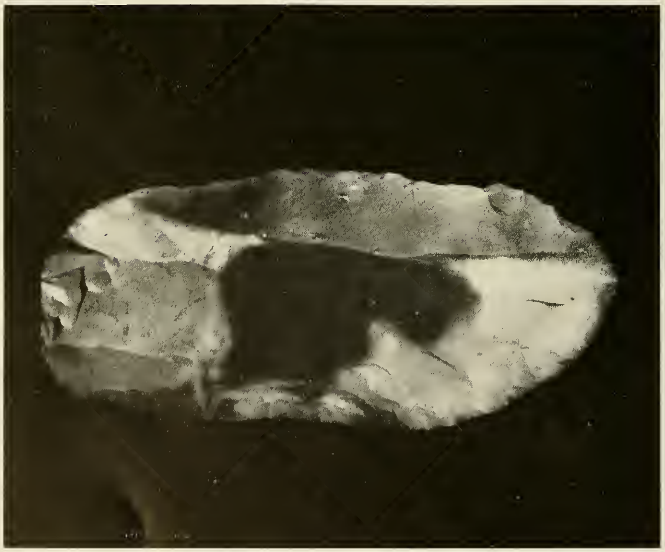
An admirable combination of the basic qualities of both core and flake tools was invented—probably by Acheulian biface-makers—in the technique known as the Levalloisian, or "prepared nucleus." This technique, which appeared in Africa and western Europe about one hundred and fifty thousand years ago, consists in preparing the nodule by flaking *before* the removal of a flake tool. By this method, the size and shape of the tool can be predetermined as for the core tools and the knapper has, in addition, the advantages of ease of execution, smooth tapering and the very sharp edge of flake tools.

This Levalloisian technique (drawings, *left*) allows the manufacture of very large flakes. In regions where flint is comparatively abundant, as in the valleys of northwestern France, it is not rare to find Levalloisian points sometimes as long as three to six inches, many of which have been only slightly retouched to smooth an outline or repair a blunted edge. It was relatively easier for these knappers to find fresh flint nodules, prepare them and flake new implements than to retouch old tools.

The situation was quite different in the Dordogne region of France, where few flint beds are available and most of the nodules are of small size. Living a less nomadic life in caves and rock shelters, the Dordogne hunters repeatedly reflaked their nuclei and tools for further use. One of the most efficient methods of preparing a nucleus for such exhaustive flaking is what we know as the Mousterian "discoidal nucleus" technique. As in the Levalloisian technique, the nodule of flint is first trimmed peripherally, but instead of trying to get one, or at best a few flakes of maximum length, the Mousterian knapper tried to get a maximum number of usable flakes. To achieve this, the nucleus was flaked toward the center—from striking platforms all around the periphery—until it was practically exhausted. The flakes obtained were then retouched into specialized tools: such as the Mousterian points and scrapers. Many scraper types were made for the tasks at hand. The basic principle of their manufacture consisted in steeply retouching the edge of the flake to obtain a thick, beveled working edge which does not dull when drawn transversely over a resistant material like wood. These scrapers were made in sizes varying from two to six inches; the most usual shapes included scrapers with straight or convex edges which evidently were used to work wood or to remove fat from hides. Concave scrapers were also made, probably for use as

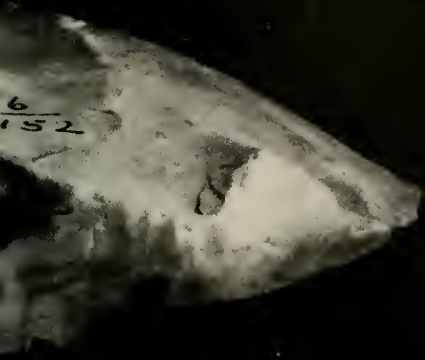


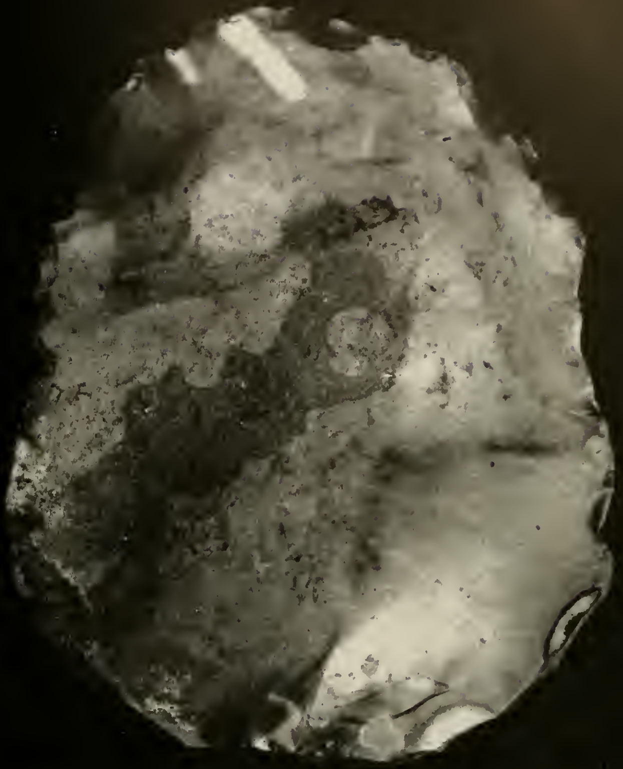
An end product of the Levalloisian "prepared nucleus" technique is shown in three positions. Outer face of the detached flake, *left*, shows the scars of knapper's preliminary preparation of nucleus (compare drawings, p. 42).



Levalloisian variation in method of preparing the nucleus is evident from this blade tool, *above*. Knapper first removed several large, parallel chips from the top of the nucleus before he detached this flake, five inches long.

Flake tool, *above*, was struck from a Mousterian "discoidal nucleus," and retouched to pointed shape. Shown by

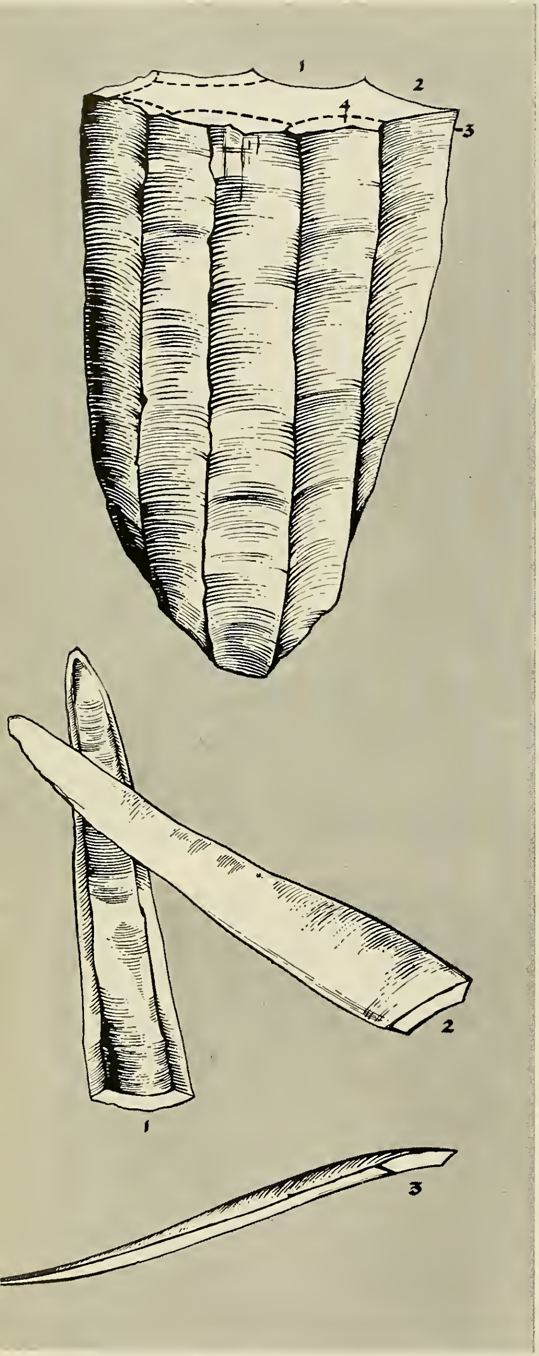




A BUTT VIEW of the same flake, *above*, shows the prepared platform (at center of photo) where the knapper struck to detach it. Smooth, bulbar face, *right*, was formed by plane of cleavage from nucleus. Specimen is four inches long.

tests to be inefficient as projectile points, tools like this four-inch-long specimen were probably used as knives.

MOUSTERIAN SCRAPER was made from a thick flake of flint by retouching the bottom edge into a steep, convex form. Working edges of this sort are strong, and this sturdy, three-inch-long tool was probably used on wood or on hides.



Third nucleus technique—for production of blades—was the key to parsimonious use of flint in Upper Paleolithic. Sequence of blows (numbers, *above*) "unwrapped" flint core.

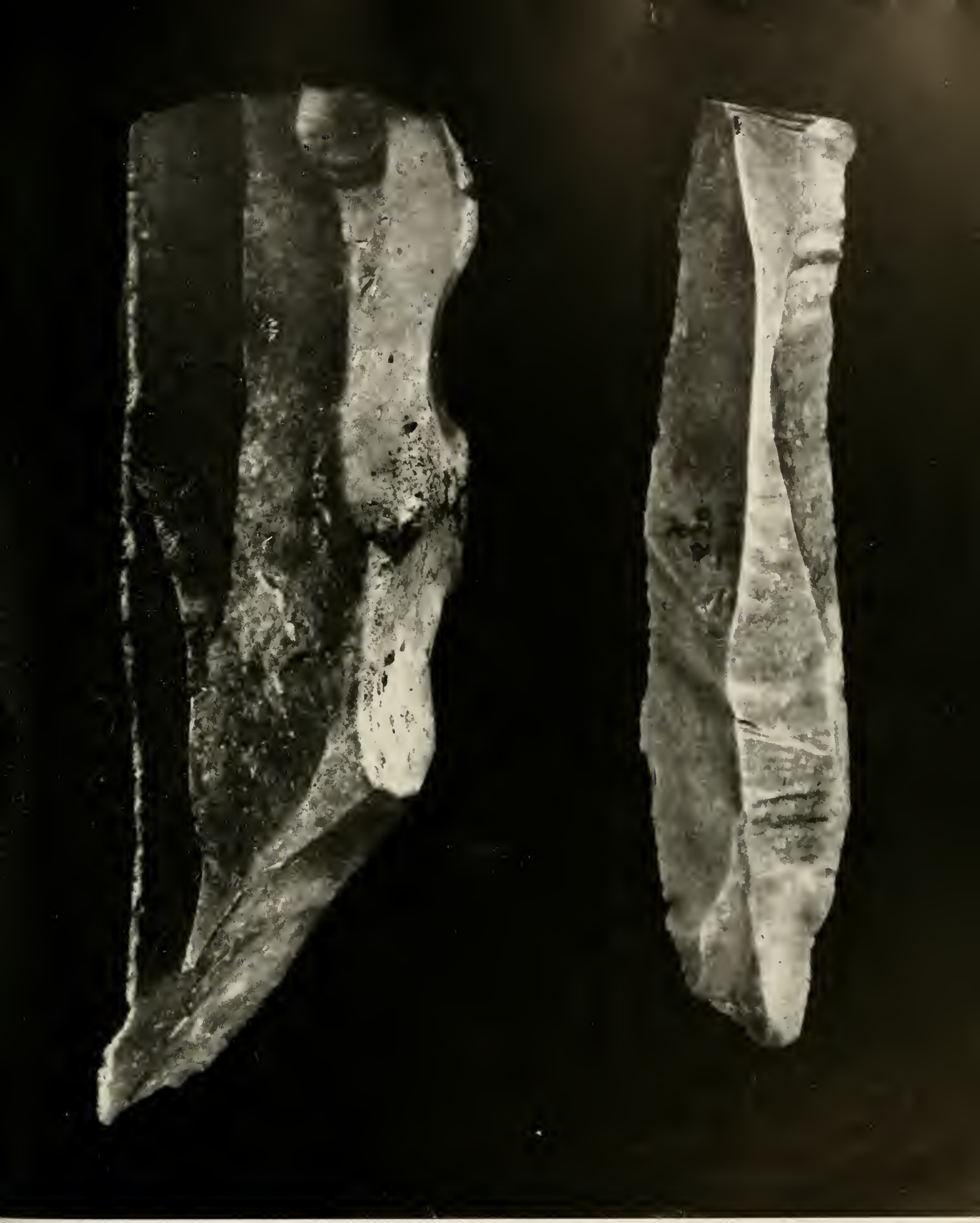
spokeshaves, to work sticks into spears, hafts and the like.

The methodical manufacture of symmetrically shaped flakes greatly increased the efficiency of the stone tool assemblage. To be sure, the edges of the early, crude types of flakes—such as the Clactonian—had frequently been retouched, so that they could be used for tasks for which the biface was unsuited. But these haphazardly shaped tools were inefficient and were henceforth replaced by a variety of symmetrically shaped flake tools of predetermined design, most numerous among them Levalloisian flakes, blades and points and Mousterian points and scrapers. Experimentation has shown, however, that these new flake tools—while extremely efficient for skinning and dismembering game—are not so useful as projectiles. The section of these so-called "points," Levalloisian and Mousterian alike, would have been too thick to penetrate the hide of the animals—such as the woolly rhinoceros, the mammoth and the bear—then hunted.

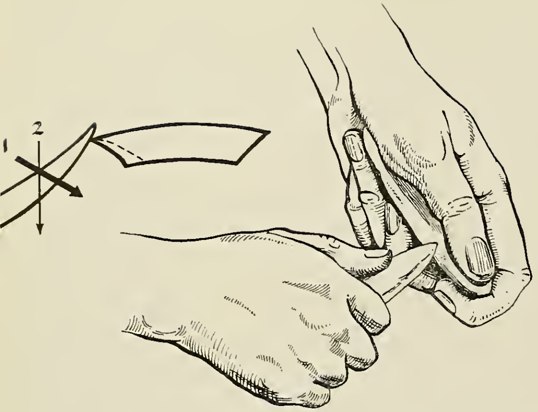
During the fourth and last glaciation, about 50,000 years ago, the Neanderthals—whose remains are found in association with tools of the Mousterian type—were succeeded by men of the modern sort. We now enter the Upper Paleolithic, the age of the great murals of Lascaux and Altamira. The very existence of these remarkable paintings is evidence of technological advance. While it is true that the environment was then very rich in game, it was the hunters' technology that enabled this society to exploit its environment effectively enough to have leisure for the creation of its art. The animal ossuaries left by these hunters have contained as many as ten thousand horse skeletons (at Solutré, in France) or nearly a thousand mammoths (at Predmost, in Czechoslovakia): mute testimony to the skill of these men and the efficiency of their stone implements.

The most important technological developments during the Upper Paleolithic included an increase in tool types made from bone, as well as stone. While some bone implements have been recovered from Lower and Middle Paleolithic sites, they are confined to a few roughly shaped pieces. Harder than wood, bone (and antler, too), they can be sharpened with suitable stone tools to finer and stronger points. Both materials were used extensively during the Upper Paleolithic to make points (with split or beveled bases for hafting), harpoon heads (with single or double rows of barbs), awls and even needles. Bone and antlers also supplied the material from which spear-throwers and other artifacts—often ornamented by carving and grinding—were made.

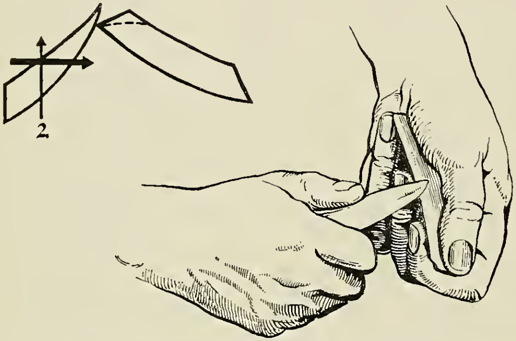
This rich development of bone and antler tools is paralleled by a multiplication of specialized stone tools. The great majority of the Upper Paleolithic stone implements were obtained by retouching one basic type of flake—a long, thin flake with parallel sides, known as a blade—which was struck from a specially prepared nucleus. The simplest way to prepare such a blade nucleus is first to break a nodule of flint in two and then, using the plane of segmentation as a striking platform, trim the half-nodule into a roughly cylindrical or conical shape (photo, *right*). The blades are then detached from the nucleus by a series of blows struck along a spiral line starting at a point near the edge of the striking platform and finishing almost at its center. Ideally, this knapping process re-



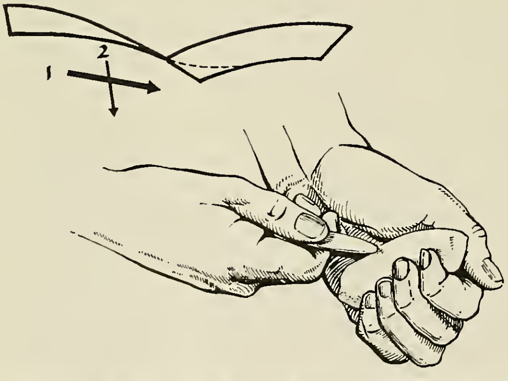
A **BLADE NUCLEUS**, *left*, and a blade, *right*, of the sort struck from such nuclei, typify the "raw materials" from which—by means of subsequent retouching—the knappers of the Upper Paleolithic made their specialized scrapers and burins. This nucleus is four and a half inches long; the blade, under four, is only a quarter-inch in thickness.



Art of retouching reached its height with development of the Upper Paleolithic technique of "pressure flaking," shown here in drawings, with examples in photo, *opposite.*



Flaking tool, perhaps a length of antler, was applied directly to blade's edge (*top* and *above*). A forward thrust, plus a twist (note the component arrows), detached a flake.



Prepared platform on blade's edge, *above*, allowed the knapper to remove even longer flakes. If the perpendicular twist (2) was used without thrust (1), the flakes were small.

sembles the unwinding and sectioning of a rolled sheet of material (see drawing on page 46).

Most Upper Paleolithic blades are thin and flat, with a trapezoidal butt and section. They have a diffuse bulb, indicating the probable use of baton percussion. The larger, thicker blades were probably struck with a hammerstone, while a certain number of blades might have been struck with the "indirect percussion" method used by some modern experimenters. This consists of placing one end of a length of bone or antler at the point on the striking platform where force is to be applied, and striking the other end with a hammerstone. The force being applied to a very restricted point, the butt of such a blade is usually small, often triangular instead of trapezoidal. It also has a more salient bulb of percussion than does a blade struck with a baton.

Professor Leroi-Gourhan, of the Musée de l'Homme, recently calculated that a flint nucleus weighing some two pounds, flaked in this fashion, would yield up to twenty-five yards of working edge, depending on the thickness of the blades struck. By comparison, a Mousterian knapper would have obtained only about two yards from a similar nucleus. A biface would, of course, be even more wasteful of flint. The single Abbevillian biface that could be manufactured from a two-pound nodule might present only about four inches of working edge, while the two Acheulian bifaces which could be obtained from the same weight of flint would provide only sixteen inches. In a manner only half-joking, Leroi-Gourhan presents this as mankind's "first economic statistic": for the development of knapping techniques that consumed less flint must have been of great advantage to prehistoric man. A hunting people could have carried only a limited amount of flint: with less wasteful methods, the range of hunting and gathering expeditions could be extended farther and for longer periods of time into areas where flint was not locally available.

Not only were these Upper Paleolithic blade tools more economical, they were also remarkably efficient. Experiments have shown, for example, that an animal may be skinned as rapidly with a "backed blade" as with a steel knife. A "backed blade" has one purposely blunted edge, on which direct pressure can be applied by the index finger. But it is likely that "backed blades," as well as other blade tools, were often inserted into split or grooved wood, bone or antler, or set in a mass of resin as is the practice of Australian aborigines at present.

Progress in knapping methods was accompanied by an increase in types of specialized tools. One of the most important of these special tools, produced in great variety during the Upper Paleolithic, is the "burin," a stone chisel which made possible the manufacture

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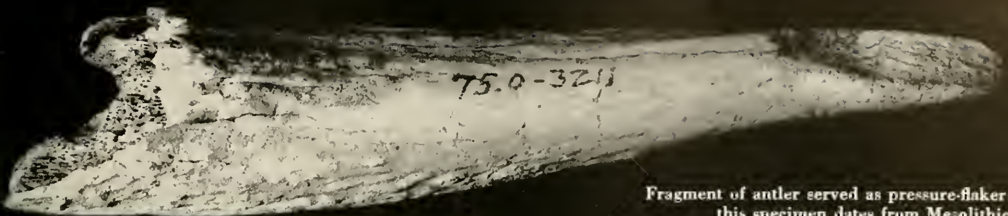
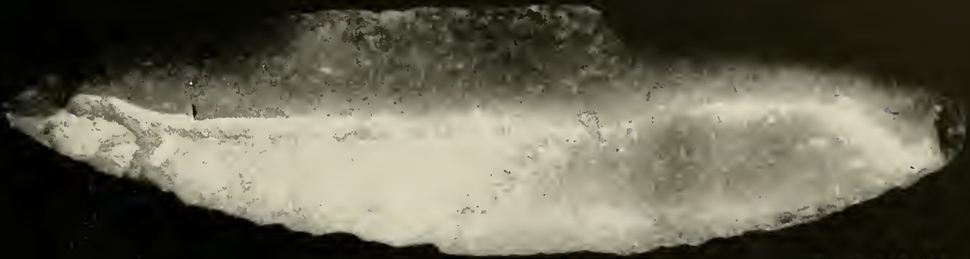
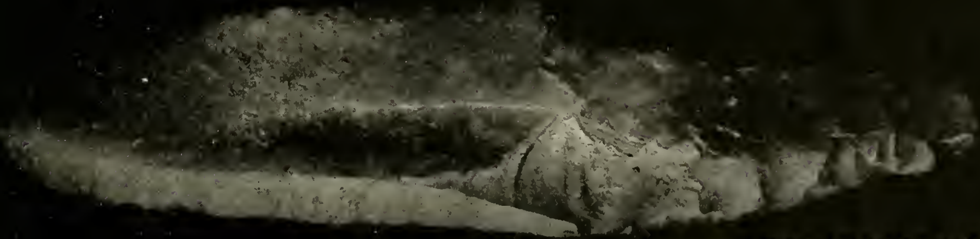
Born and educated in France, Mr. Bordaz is presently an instructor in anthropology at Columbia University. In this article, he has drawn mainly on the experimental work of five prehistorians: A. S. Barnes and Sir Francis Knowles, of England, and F. Bordes, L. Coutier and A. Leroi-Gourhan of France. The accompanying photography, by Lee Boltin, uses a monochromatic light source, a technique first applied to prehistoric stone implements by G. Tendron, whose own study of a Solutrean blade is shown on pp. 36-7. The lamps were provided by the G. W. Gates Co., of New York. Mrs. Zallinger, a well-known artist, here makes her first appearance on these pages.



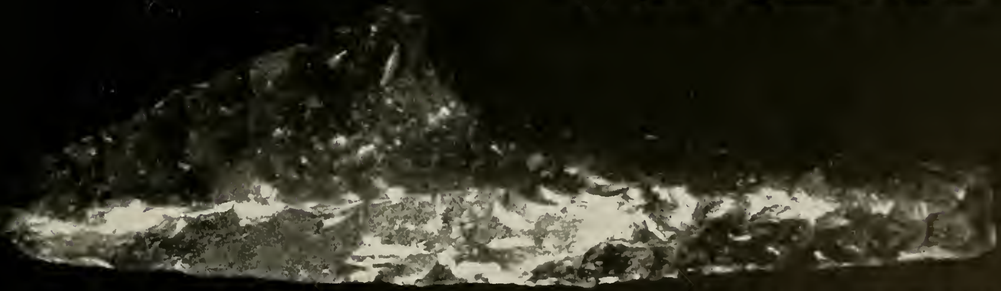
Fragment of antler served as pressure-flaker: this specimen dates from Mesolithic.



Two-inch shouldered point was made from a small, narrow blade.



Haft end of this three-inch point has been pressure-flaked on one face.



Two-inch point has been symmetrically shaped and thinned over both its faces.

TRIO OF PROJECTILE POINTS shows some varieties of Solutrean pressure-flaking technique. All have been made by retouching blades, but the first (below tip of antler) has had only part of edge retouched, to assist hafting. Stem of the second point is more extensively worked on one face, and third point has been pressure-flaked over entire surface.

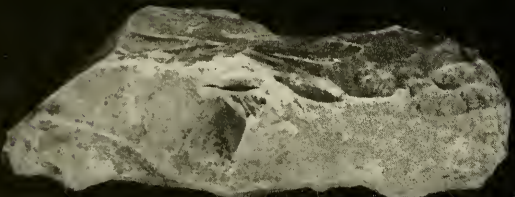
of bone and antler implements on a large scale. Now, unretouched blades or flakes are of little value for working hard materials such as bone or antler. Their thin sharp edges, so useful for cutting skin and flesh, blunt quickly. The retouched edges of the scrapers are stronger, but even these do not possess the proper shape for carving these hard materials. Only the burin, of which many types were made, gave the Upper Paleolithic craftsman the chisel-like cutting edge he required.

Burins were used principally to carve longitudinal grooves in bone and antler, isolating slivers of material that could easily be pried off once the underlying, spongy tissue was reached. These slivers were then finished by carving, scraping and grinding with abrasive stone into projectile points, awls, needles and the like.

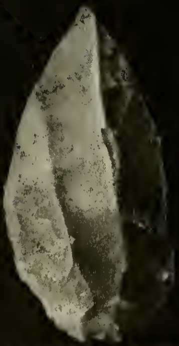
The second most common tool in Upper Paleolithic levels is the "end scraper," a blade that has been sharply retouched at one end. It is similar to a stone implement still in use among the Australian aborigines. Set into a hand grip, it can be used as a "composite tool," scraper at one end, knife on both sides. Such composite, or multiple-blade, tools were common in Upper Paleolithic times: examples include burin-scrapers, double perforators, and end scraper-perforators.

The diminishing size and increasing specialization of the Upper Paleolithic tools was accompanied by still another technical advance: the development of "pressure-flaking." This technique allowed far greater precision in retouching than does percussion-flaking. The implement used for such pressure-flaking could sometimes have been nothing more than a flake with a square edge, or the surface of an anvil stone. More usually, it probably was a wood, bone or antler implement. One end was applied close to the edge of the tool to be retouched and the knapper then pressed sharply, with a forward thrust, detaching a flake (drawings, *p. 48*).

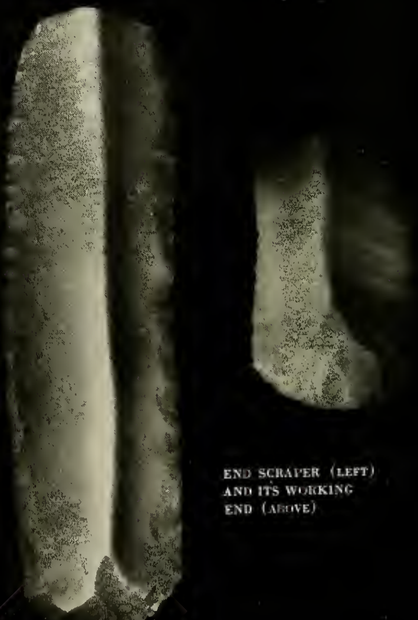
Possibly the most spectacular tools of all the Paleolithic —the almost unbelievably delicate and handsome Solutrean "laurel leaves"—were produced by means of such pressure-flaking. The longest laurel leaf ever found was part of a cache of fourteen found near Volgu, in southeast France. This magnificent blade measures thirteen and three-quarters inches in length by three and three-quarters



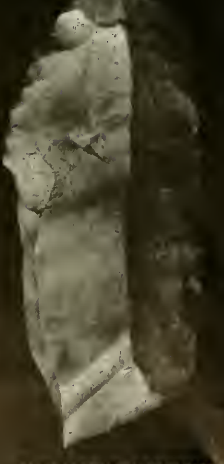
AURIGNACIAN KEEL SCRAPER



SOLUTREAN COMPOSITE: "BEC DE FLUTE"—END SCRAPER



END SCRAPER (LEFT) AND ITS WORKING END (ABOVE)



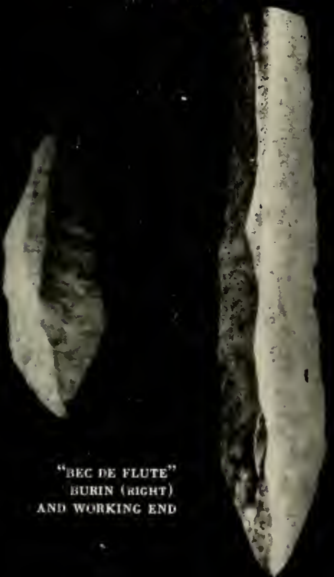
MAGDALENIAN COMPOSITE: ANGLE BURIN—END SCRAPER

Hypothetical "tool kit." of Upper Paleolithic period, has been assembled here from sites of varying date. The knife (top, *right*), side-hafted in a grooved piece of wood, is actually from a Swiss neolithic site, but it is probable that some tools were set in similar fashion in wood, bone and antler by paleolithic artisans. All of the tools, except for the heavy-inches at its widest—and is only slightly more than a *quarter* of an inch thick! Solutrean laurel leaves were probably first shaped with a baton before being retouched by the pressure technique. It is likely that the admirably controlled flaking exemplified by these implements was made possible by the preparation of carefully set platforms for the necessary percussion and pressure.

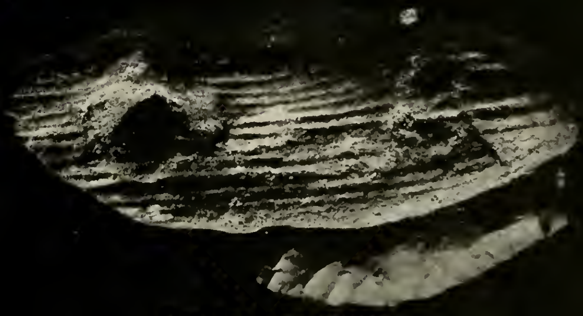
The largest Solutrean laurel leaves were certainly not used as lance or javelin points: they could have been too easily broken by lateral stresses and would have shattered had they missed their mark. The obvious fragility of certain very large specimens suggests ritual use. But most of the leaves were probably used as knives—by means of inserting an edge (or one of the ends) in a piece of grooved wood, bone or antler. There is good reason to believe, also, that the smaller, thicker Solutrean leaves, as well as a few other points made at the same time (such as the shouldered point), *were* projectile points.

MANUFACTURE of these elegant stone leaves was not continued in the following period—the Magdalenian—that marks the end of the Upper Paleolithic. The Magdalenians are known to us principally by the beauty of their mural paintings (such as those found at Altamira) and for their bone and antler implements, often beautifully carved and sculptured. Their flint tools generally resemble the earlier types of the Upper Paleolithic. It is notable, however, that late Magdalenian times bring an increasing use of very small blade fragments—retouched into implements of geometric shape, usually less than one inch long, called "microliths." These microliths, which became even more important in a later period called the Mesolithic, mark the culmination of a trend toward smaller flint implements.

The Magdalenian was the last period of the Paleolithic in western Europe, where it coincides with the end of the fourth glaciation. The environment at that time underwent radical changes. Tundra and steppe—with their vast herds of horses and reindeer—gave way to pine and hardwood forest inhabited by elk, aurochs, deer and boar. New types of implements, and new techniques of manufacture, were necessary to deal with these new conditions. An account of these developments will be presented in PART II of this discussion.

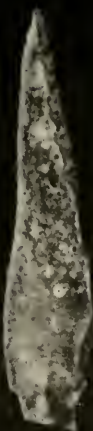


"BEC DE FLUTE"
BURIN (RIGHT)
AND WORKING END



KNIFE, SIDE-HAFTED IN WOOD

duty scraper (top, *left*), were made from blades: all were retouched into their present forms by pressure-flaking. The Gravettian point (first of three, *right*) could have been used as a knife or may have been side-hafted as the blade of a spear. All the implements shown here are reproduced at a common scale, ten per cent larger than actual size.



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REVIEWS *(Continued from page 6)*

inheritance of all members of his species. Since the authors postulate that a great part of all behavior is guided—or at least set into motion—by these preorganized systems, it follows that behavior on all levels is, to a great measure, predetermined at birth.

DETAILED criticism of this theory is beyond the scope of this review, but even a casual reader of *Instinctive Behavior* will find himself with some disturbing questions unanswered.

First and most obvious is the lack of any link between the mechanism suggested and the actual mechanism of the physical nervous system. In a summing-up paper at the end of the volume, Lorenz mentions a hierarchic arrangement of instinct patterns postulated by Tinbergen as parallel to a similar arrangement which has been shown to exist in the central nervous system. The statement is not overwhelmingly convincing, since the simple pyramidal structure discussed is one of the basic patterns of nature that shows up in every context from architecture to military tables of organization. Certainly such organizations of behavior mechanisms and of nerve cells could exist and could be connected or even equivalent. But until the two are linked, the statement is routine speculation.

The ethologist viewpoint as put forth in this book is based almost entirely on observation and preliminary experiments in selected aspects of the behavior of wild and laboratory animals. Such observation is of obvious importance, but would seem to be a lopsided foundation on which to erect a theory which blueprints the whole organization of the mind.

Where, for a single example, do the profound effects of body chemistry and hormones fit into the picture? Do they have as much, more, or less effect than the rather crude external sensory stimuli, which are the releasers in this theory?

One also wonders what role body structure might play in certain "instinctive" acts. Is the basic neck-stretching action typical of a gray goose retrieving an egg that has rolled from her nest entirely an innate nerve pattern, or is there only one anatomically possible or efficient way in which a goose can retrieve an egg?

The reader may also question the objectivity of observations that are consistently recorded in highly subjective and often even novelistic terms. To write that a brooding bird "could not bear" the sight of an egg outside her nest argues a certain lack of detachment in the observer, particularly when he adds that: "This subjective interpretation is perhaps less naïve than it may appear at first sight, since we (meaning the

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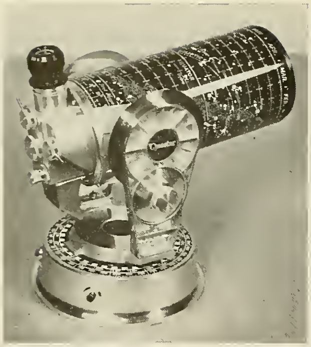

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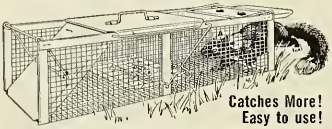

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observer and his associates) have had comparable experiences in just such situations where . . . innate releasing mechanisms and instinctive actions play the lead." There is no question about someone's emotions being involved here, but are they the goose's? Who, in short, watches the bird watcher?

For obvious reasons, those who would psychologize about behavior stand in more than average peril of the always-present hazard of scientific investigation—generalizing from insufficient data. In a field where so little is firmly known, even a provisional working hypothesis can look comfortingly stable and misleadingly important. And the temptation to pile one hypothesis on another to build a viewpoint is hard to resist.

This, it would seem, is basically what has happened to the serious and able scientists who have contributed to this collection. In their eagerness to extract full value from their work, they seem to have ended with debatable theory in the place of valid observations connected by

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NATURAL HISTORY, Volume LXVII

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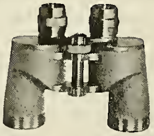

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a chain of hard logic. At best, their theory seems to raise a good many more questions than it answers.

An unsound scientific theory is never a healthy companion: in the field of behavior, such theories offer particular dangers since they may gain acceptance by men working in other specialized fields who have neither the time nor the background to criticize the theories on their own merits. This is particularly likely to happen in the highly empirical field of clinical psychology. Psychiatrists and psychoanalysts, devotedly preoccupied with particularities of human behavior, are naturally eager for any map or landmark that will help them orient themselves in the complexities and confusions of the mind.

A basic "theory of instinctive behavior" could be a tremendous landmark in this vital work, as in the whole field of psychology. But ethologists, on present evidence, have yet to raise their hypotheses to the dignity of theory or even to establish their merits as hypotheses.

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FIT TO BE TIED, the caddis forms part of fish diet — whence lures like this.

CROESUS AMONG THE INSECTS

This creature's larva constructs its case of many materials—sometimes even of gold

By JAMES M. BRENNAN

CADDIS FLIES are weakly, dun-colored, insects of mothlike appearance, related to the moths and butterflies. Although they are relatively common — they number about 3,000 species in the order Trichoptera — caddis flies are mostly unfamiliar to both the layman and the general student. Freshwater anglers, however, make frequent — if insensible — contact with these insects. As the fisherman brushes along vegetation overhanging ponds and streams, he will cause virtual clouds of them to fly up suddenly and uncertainly from the alders and willows. But more familiar to the fisherman, as he seines and screens the stream bottom for live bait, are the case-bearing caddis-fly larvae ("caddis worms"), which form a substantial part of the diet of game fish. In fact, long ago, makers of artificial lures were quick to take advantage of this dietary preference by tying the wet fly known to fishermen in the western United States as "rockworm"—a name which applies equally well to the larva itself.

THESE case-bearing larvae hatch from a mucilaginous egg mass glued to some object, such as a rock or stem, beneath the water's surface. Each larva constructs a shelter composed of a more-or-less tubular case of silk, open at either end, to which are cemented foreign materials — such as bits of sand and gravel, seeds, twigs, shells and leaves. The anterior opening of the case is wide, to permit protrusion of the head and legs of the rockworm which—by means of tough caudal hooks — maintains a firm hold of its covering as it crawls ponderously along the bottom.

When fully grown, the larva closes each end of its case with silk, pupating therein without making a cocoon. When the emergence time approaches, the pupa bites its way out of the covering and swims or crawls up to the surface, where the adult soon emerges and takes wing.

IN quest of materials for their shelters, all rockworms are not as fortunate as the opulent individual whose case is illustrated here (*right*). This insectival Croesus constructed a veritable gem-studded shelter for itself. In addition to the usual grains of sand, particles of gravel and woody elements, its case conspicuously displays fragments of columbite, a bit of cassiterite and two gold nuggets.

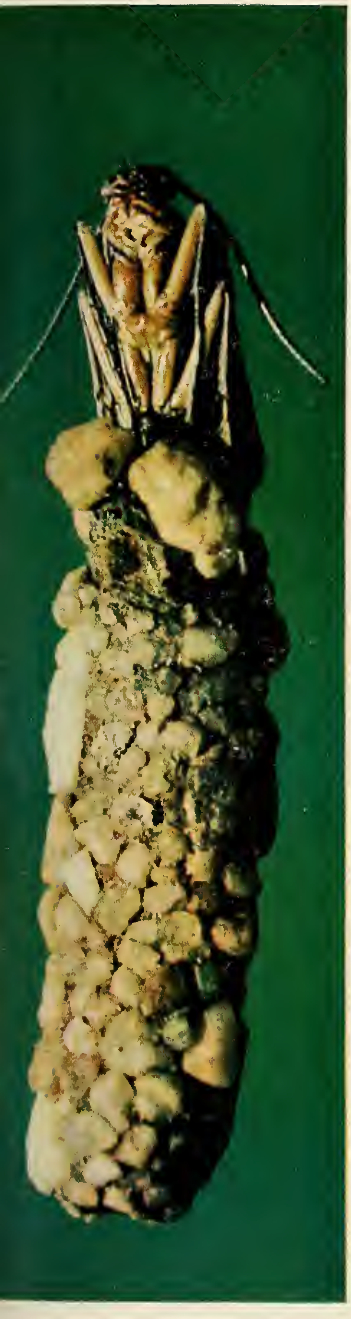
As pictured, the blue-black, striated stones lying between the easily recognized gold nuggets are columbite, the basic ore of columbium (which, prior to 1957, was known mostly as a carbide stabilizer in stainless steel). Today, columbite — since it does not suffer radiation damage and surpasses other metals in resisting heat and corrosion — has become important in nucleonics, as a fuel-alloying element and as a fuel cladding in fast reactors.

The brown-flecked, black stone that touches the upper right corner of the larger gold nugget is cassiterite (also referred to as "stream tin" or "tin stone"), the basic ore of tin.

THIS unique caddis case, just one inch long was made by a larva of the family Limnephilidae. It was found in a sluice box by Mr. and Mrs. Asbury Smith of Hamilton, Montana, while they were placer-mining on a creek near their home, and was brought to my attention by a local "rock hound," Martin E. Shoffner, who also identified the ores.

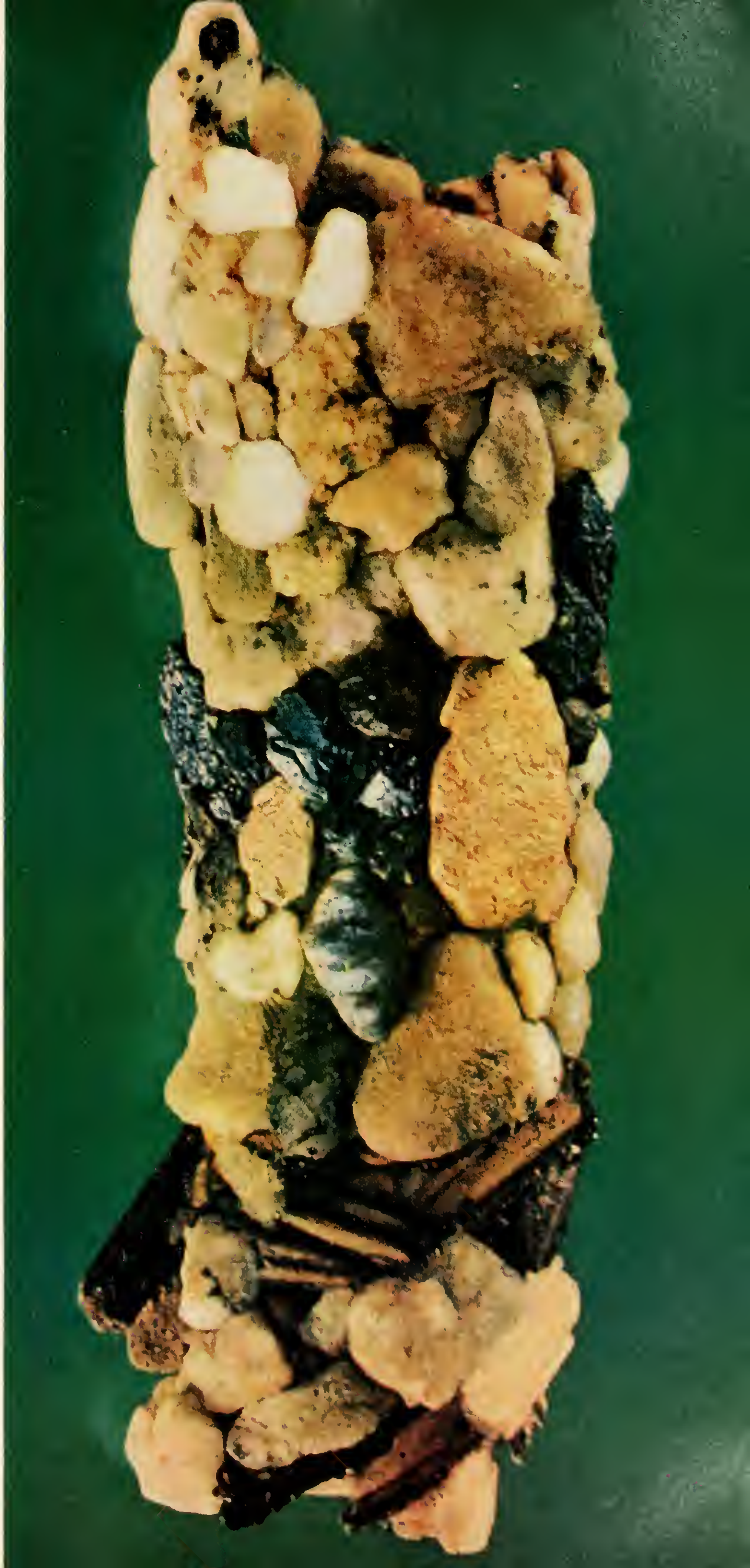
Lest eager fortune-seekers be falsely encouraged, and to forestall any new gold rush to old Montana, it is advisable to report that the intrinsic value of this caddis-fly case is less than the market cost of one wet fly simulating it; that the value of gold taken from the creek where it was found, during the more than half a century for which we have records, is less than $260,000, and that only now is a columbite operation—of uncertain future—opening in this part of the Golden West.

DR. BRENNAN is an entomologist who, after a period of teaching, took up work with the government. He is now with the U.S. Public Health Service.



Head and legs of caddis, *above*, extend from silken case embedded with debris.

Gold-studded caddis-fly case, at *right*, also contains bits of sand, wood, ore.



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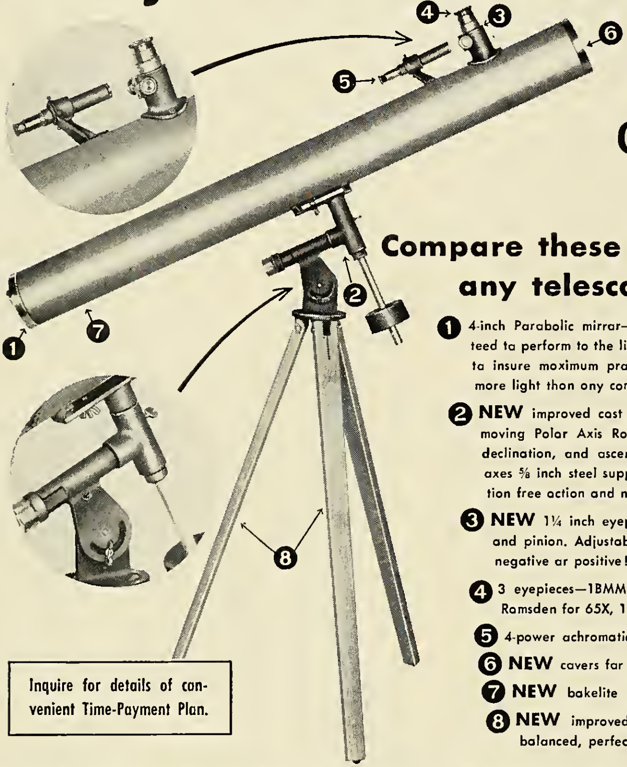

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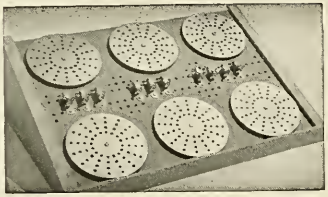

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THE EMPEROR PENGUINS of Antarctica have appeared mysterious ever since the first rookery was discovered in 1902 by the explorer Wilson, on one of Scott's expeditions. The evidence forced him to conclude that the emperors arrived with autumn and mated in the depths of the polar winter, raising their young on a small area of sea ice. Of all antarctic birds, only they follow this cycle. Some little additional information about the emperors was slowly gathered, sometimes painfully: Cherry-Garrard has described the terrible journey he made in quest of some emperor eggs. But no one had ever observed these birds carefully over a long period of time until, in 1952, a French expedition set up an outpost at an emperor rookery. The results of this ten months' study are told on page 66.

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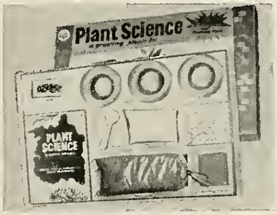

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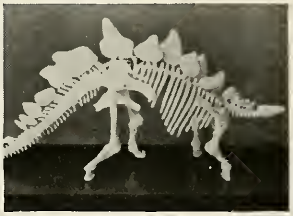

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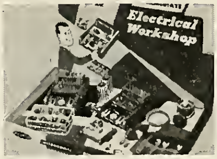

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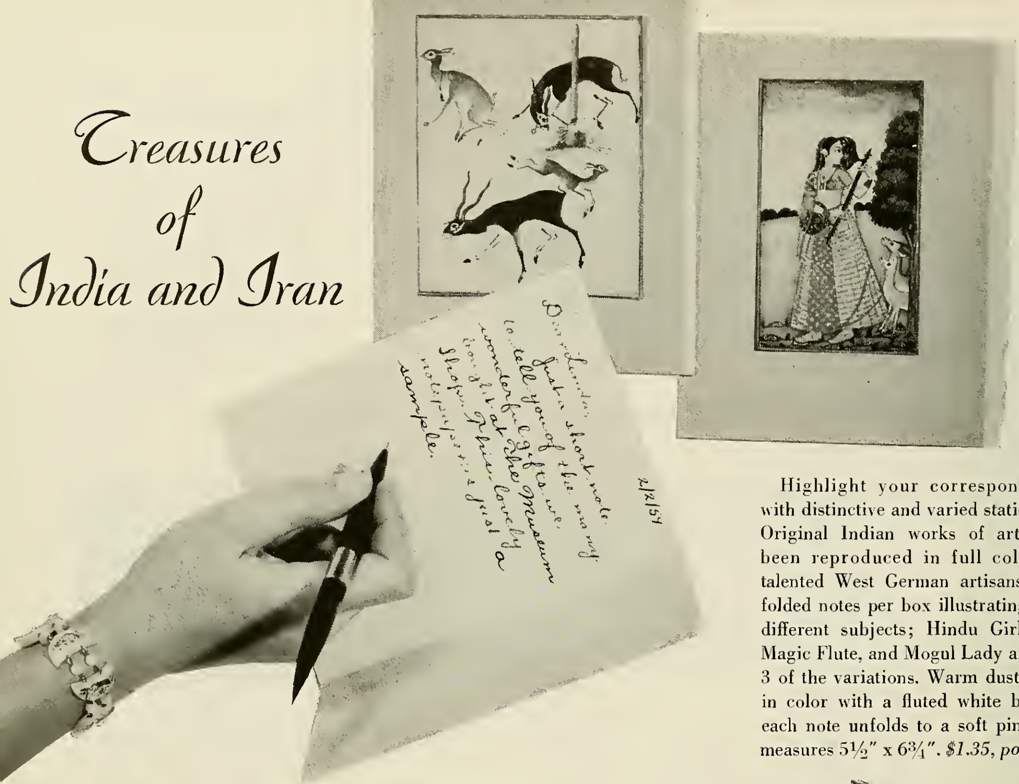

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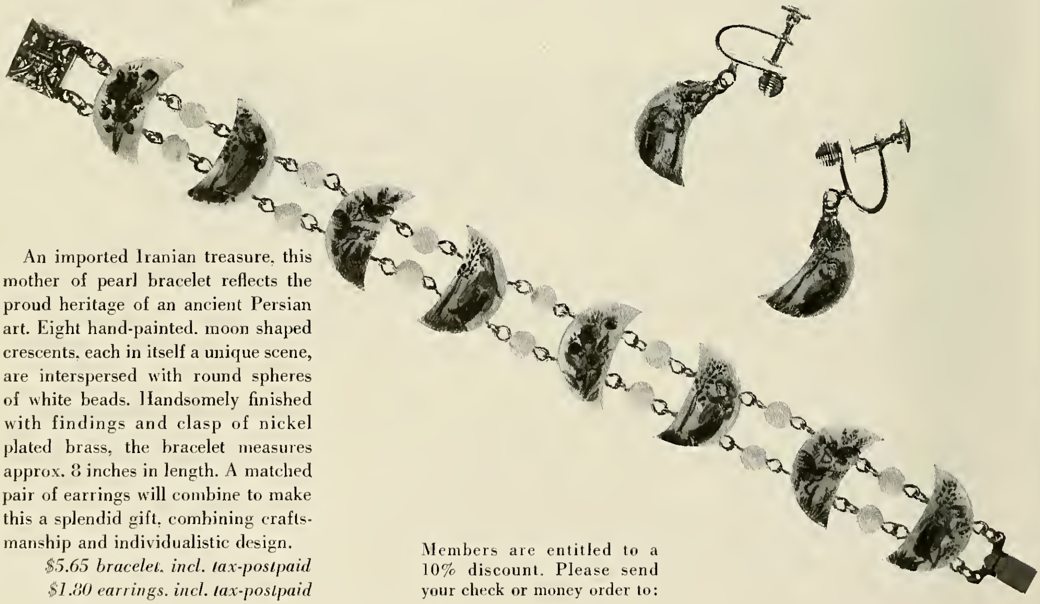

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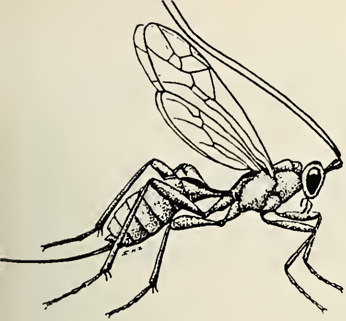


Reviews in Brief

The Fascinating World of Butterflies, edited by L. Hugh Newman. *Hanover House, $4.95; 92 pp.* The World of Butterflies and Moths, by Alexander B. Klots. *McGraw-Hill, $15.00; 207 pp.*

Two books covering roughly the same territory, but of very different quality. Newman's book, an adaptation from Charles Ferdinand's *Les Plus Beaux Papillons*, consists almost entirely of photos, some of them good, some routine and all rather poorly reproduced—although it would be ungracious to criticize the reproduction when it allows us to get around a hundred large photos for $4.95. But there is almost no text; and it is hard to understand why publishers persist in presenting such fascinating material with little or no explanation of what it is all about. Inevitably, this lack of concern is reflected in the photographs, also, many of which have no particular story to tell.

The Klots book, on the other hand, is a model of its kind: the photos are good, some of them are really extraordinary, and they are accompanied by a text which is as thorough as it is readable, presenting virtually everything of interest to a nonspecialist while incorporating the results of the most recent scientific study. This is particularly true of the chapters on Lepidoptera as predators and prey, and on their senses, habits and behavior—which will come as a revelation to many readers. Of course, one has to pay for all this, but it is worth it.

A Short Introduction to Archaeology, by V. G. Childe. *Macmillan, $2.50; 142 pp., illustrated.*

A rather more serious book than the following, more succinct and more authoritative. In approach, it is quite different: instead of a historical treatment, Childe has grouped his material by topic and technique (e.g., stratigraphy, mounds and flint work). He is thus able to convey a great deal of fundamental information in a very meaningful way, and to give an idea of what archeology is like, to its practitioners, as a science.

The Story of Archaeology, by Agnes Allen. *Philosophical Library, $4.75; 245 pp., illustrated.*

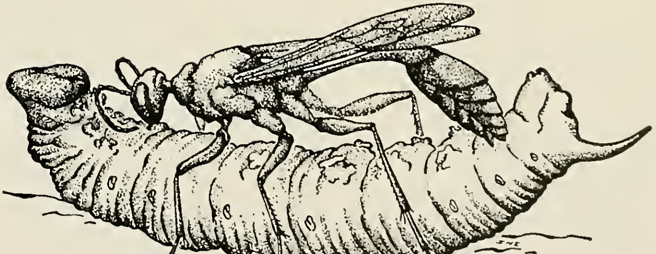
A quiet, if somewhat abbreviated, account of what archeological investigation has taught us about mankind, from "the earliest toolmakers" to the high civilizations of Egypt, the Near East, Greece and Rome. Very little attention is devoted to Mexico and Central America. All in all, sketchy, but pleasant enough to read.

The Arctic Year, by Peter Freuchen and Finn Salomonsen. *Putnam, $5.95; 348 pp., illustrated.*

Freuchen needs no introduction, except perhaps to stress that he was not only an adventurer and explorer in the great tradition but a very serious student of arctic life as well. Finn Salomonsen is less familiar to a broad public—which is a pity, for the Danish zoologist knows as much about the arctic in general as any man. Between them, Freuchen and Salomonsen have produced a first-rate book. Its plan is both simple and comprehensive: instead of treating their subject animal by animal and plant by plant, they follow the course of the seasons, describing changes and adaptations as they occur over the entire range of nature month by month. The picture of arctic life that this method enables them to build up is very complete, and it has much less of a bookish, artificial quality than a grouping by topics would have. This is one of the rather few recent books to combine the researches of the modern biologist with the more casual style of the traditional naturalist, and it ought to make fascinating reading for one and all.

Matter, Earth and Sky, by George Gamow. *Prentice Hall, $10; 593 pp.*

George Gamow has had two distinguished careers, as a physicist and as a writer of science books for the layman. His latest "popularization" is by far his most ambitious, for it attempts nothing less than an integrated survey of physical science. The book that has resulted represents a challenge without compromise to the reader. Written with sureness and clarity, it is easy to read but certainly not easy reading. It presupposes a reader intelligent enough to realize that information can only be acquired through the use of intelligence, not by being entertained. To anyone who is willing to apply himself on these terms, *Matter, Earth and Sky* offers the greatest spectacle of the twentieth century—a view up the majestic avenue that runs from the interior of the nucleus to the ends of a universe that, it seems, may very well have no end.



Ammophila wasp with caterpillar, *here*, and ichneumonid wasp, *top*, are taken from Klots.

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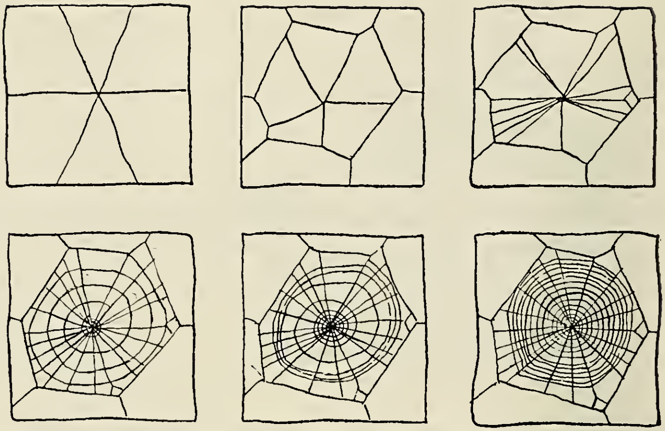
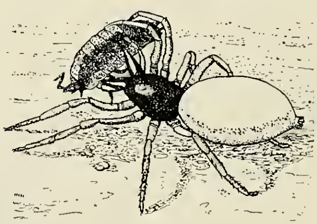


SUCCESSIVE STAGES involved in spinning of orb-web are shown after Cloudsley-Thompson.

SPIDERS, SCORPIONS, CENTIPEDES AND MITES, by J. L. Cloudsley-Thompson. *Pergamon Press, $9.00; 228 pp.*

THIS EXCELLENT book concerns "the ecology and natural history of wood lice, 'myriapods' and arachnids," as its subtitle informs us. These creatures are perhaps not as popular as they should be—except among certain children, who are usually considered to be a bit perverse by their parents—and to some extent they justify the wide aversion they have inspired: the androphagous habits of female spiders are well known. These are, notwithstanding, fascinating creatures, whose behavior—which is what the author devotes most of his attention to—is engrossing enough to stand comparison with that of any animal. The book, which is written by a London zoologist, tends to emphasize the British species at the expense of the American ones. And speaking of expense, this is the book's only real fault: $9.00 is rather a lot to pay for 228 pages, even these days.



"DISDERA" is shown, *above*, with its prey.

THE TARANTULA, by William J. Baerg. *University of Kansas Press, $3.00; 88 pp.*

OF ALL SPIDERS, tarantulas are the object of the gravest misconceptions: in fact, they seldom bite, and they are not poisonous except in a few species. Baerg's little book gives a capable and interesting summary of what is known about these creatures.

THE LANGUAGE OF ROCKS, by Fritz Berckhemer; NATURE AS ARCHITECT, text and photographs by Horst Janus. *Frederick Ungar, $4.50, 119 pp., each.*

THE two initial volumes of this publisher's "Art and Nature" series—books consisting largely of photographs with expository captions—exploit the close-up view of unexpected shapes and textures. The former deals chiefly with fossils, the latter with the designs in organic life. *Nature as Architect* is the better reproduced of the two. Unfortunately, more imaginative photographers have previously noted flies' mosaic eyes, the miniature pueblos of crystals, and the hypnotic tracings on leaves and insect wings: these are good photographs, but, in general, nothing that has not already been seen.

LIGHT, by Eduard Ruechardt, *$4.50; 201 pp.* EBB AND FLOW, by Albert Defant, *$4; 121 pp.* THE BIRDS, by Oskar and Katharina Heinroth, *$5.; 181 pp. University of Michigan Press.*

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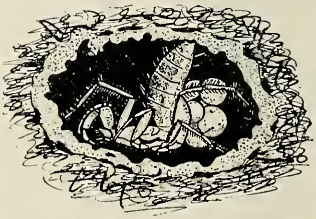

"SCHIZOMUS" here guards her eggs in nest.

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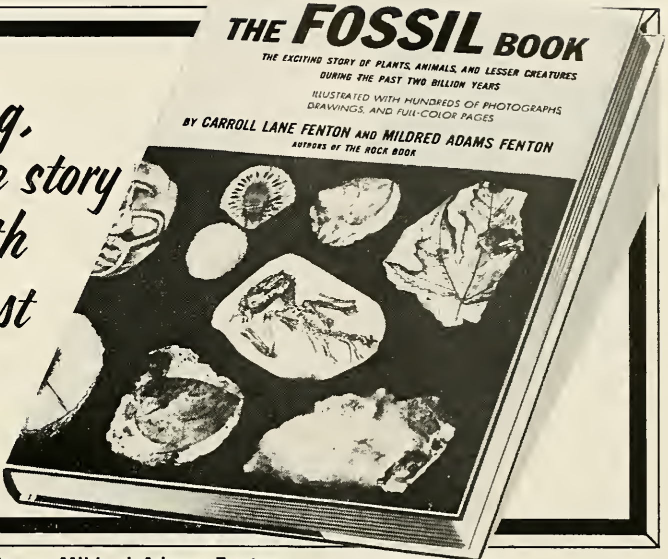
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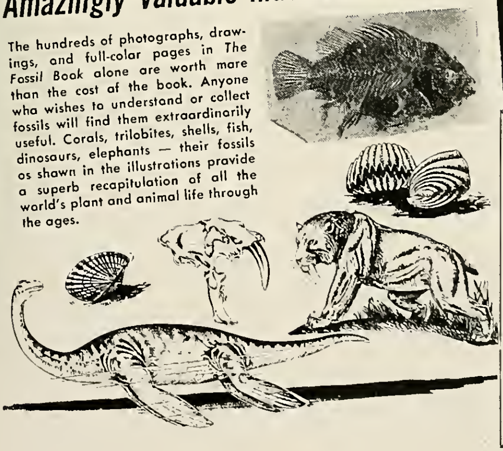

ABOUT THE AUTHORS: Dr. and Mrs. Fenton are well-known geologists and paleontologists whose *Rock Book* is the standard work in its field. In addition to holding important academic posts, they have been active in field research — among the specimens discussed and illustrated in the book are the world's oldest known fossil shells, which the authors discovered near White Sulphur Springs, Montana. In addition to *The Rock Book*, the authors have written *Our Amazing Earth*, *Our Living World*, *Giants of Geology*, and *Our Changing Weather*.

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of information into a small space. This is particularly true of the volume on birds, which manages to provide an excellent introduction to the whole field of ornithology in less than 180 pages. The volume on light tells as much or a little more than a student might glean from a college survey course in general physics, while *Ebb and Flow* will certainly answer any questions that a non-hydrographer is ever apt to ask about the tides. It is a pity, however, that such slender volumes could not have been issued at more moderate prices, perhaps in a paperback edition.

GETTING ACQUAINTED WITH MINERALS, by George Letchworth English and David E. Jensen. *McGraw-Hill, $6.95; 362 pp., illustrated.*

A REVISION and enlargement of a standard handbook, this bible for rock hounds and amateur lapidarists could tempt almost anyone into the mineral-collecting hobby. The first third of the book discusses the general characteristics of minerals, with information about collecting, examining, testing and displaying specimens. An extensive group of mineral descriptions follows, including most of the types the beginning amateur is likely to encounter, as well as a brief section on rocks. The final part of the book, a system of mineral identification, is practical and well-adapted to amateur use. As a whole, from its accurate, well-written text to its clear photographs and workman-like design and typography, this manual could serve as a model and a challenge to authors and publishers planning a natural science guide in any field.

FLOWER CHRONICLES, by Buckner Hollingsworth. *Rutgers University Press, $5.00; 302 pp., illustrated.*

MRS. HOLLINGSWORTH has apparently done a substantial amount of research for *Flower Chronicles*, and she has come up with any amount of interesting lore concerning garden flowers—the rose, poppy, marigold, iris and lily, for example. These she discusses in their real or reputed uses as medicine, poison, food and love potions, as well as in their symbolic relation to war and poetry. The illustrations are handsome.

GEORGIA BIRDS, by Thomas D. Burleigh, illustrated by George Miksch Sutton. *University of Oklahoma Press, $12.50; 746 pp.*

THIS BOOK, we are told, has been in planning and preparation intermittently for over thirty years, but it was well worth the wait, for the result is one of the handsomest volumes to have come along in some time. Two introductory chapters (a history of Georgian ornithology, by William W. Griffin, and a survey of the state's physiographic and biogeo-

(*continued on page 105*)

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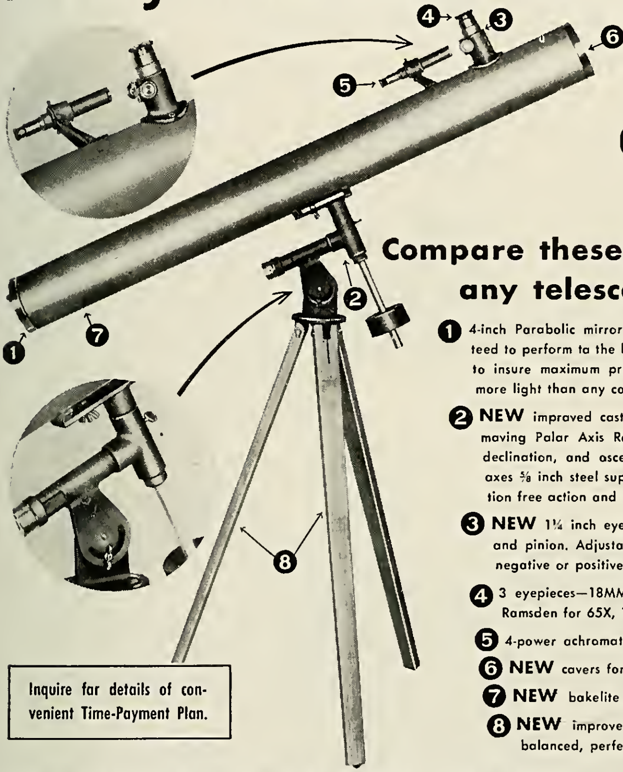

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POLAR REALM OF THE EMPERORS

Antarctica's emperor penguins breed in the winter, against frightful odds

By Jean Rivolier

MANY PEOPLE like to suppose that Captain Cook discovered all there was to discover about the southern hemisphere, so that—by the time of his final voyage—the civilized world was fully informed about its islands, its native population and its animals. Without examining this convenient theory too closely, it certainly seems that Cook met some emperor penguins during his second voyage, nearly two hundred years ago.

Forster, the naturalist of the 1775 party, classified all his drawings of penguins as *Aptenodytes patagonica*. Sixty-nine years later, in 1844, Gray made a study of Forster's penguin sketches and noticed that one of them, very like the other sketches in many respects, betrayed a number of small distinguishing features. A few weeks of study and reflection were sufficient to make ornithologists believe that Forster had been the first to see an emperor—known by then in Europe from pickled specimens. They felt they ought to call this new kind of penguin something, so they Latinized the name of Forster. And since no one was able to prove that *forsteri* was *not* a *patagonica*, the second name remained too.

Still, as late as the end of the nineteenth century, no one had discovered where or when the emperors laid their eggs, what their chicks were like or how long it took them to grow into

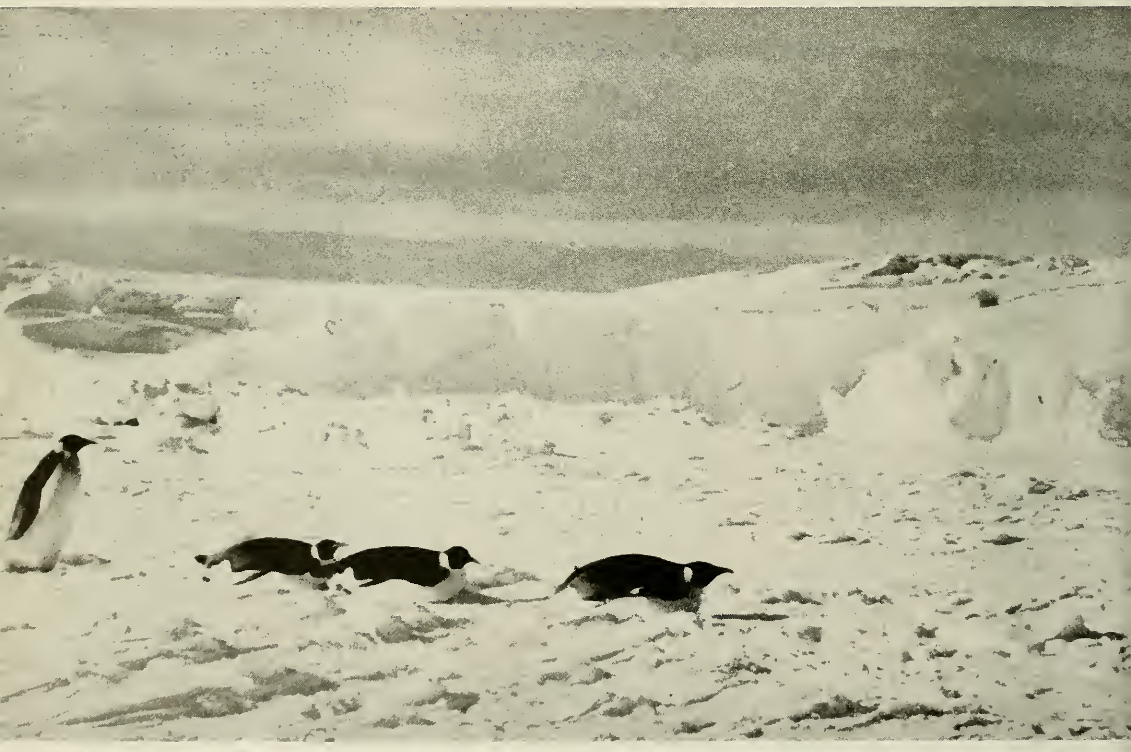
Emperors' rookery at Géologie Point is seen, *left*, in March, as the antarctic winter and breeding time begin. *Above*, French cameraman films the emperors.

adults. It was to Dr. E. A. Wilson—the English naturalist–physician, who died so tragically with Robert Scott—that the chance fell of discovering the first emperor penguin rookery. But not until he had paid four visits to the rookery in the course of two years, during 1902 and 1903, would Wilson allow himself to accept evidence which at first seemed incredible. The fact to which he had to reconcile himself was that the emperors arrived in autumn, laid their eggs on a small stretch of sea ice and reared their young in the heart of the antarctic winter. Why was this so hard for him to accept? Because the rest of the penguin family—and every other bird in Antarctica—came and went in the reverse order.

WILSON returned to the Antarctic with Scott in 1911. This time—in the middle of winter—he made a special journey to the rookery with two of his colleagues. Cherry-Garrard and Bowers. Cherry-Garrard has left us a full account of the terrible journey. He and his two companions dragged their heavily laden sledges completely unaided. They marched in total darkness. their hands were severely frostbitten and they could not touch metal without stripping skin from their fingers. On the march, their faces were covered with masks of ice; at night, their sleeping bags froze over their heads, stifling them. The temperature was a hundred and eight below. Their feet could be completely frostbitten, for all they knew: there was no feeling left in them. For more than three weeks, they trudged through the bleak horror of night, the monotony of the frozen waste unbroken by even the slightest gust of the antarctic wind.

By the time they reached the rookery, they were beginning to get short spells of daylight. They saw the emperors and gathered the reward of all their pains—five eggs. Then they turned back, and somehow—fighting off exhaustion and scrambling free of the crevasses into which they occasionally fell—they reached their base. Two of their five eggs had smashed, but, in spite of everything. they managed to bring three back intact.

A SECOND ROOKERY was discovered by Mawson. on Haswell Island, in 1914 and Shackleton found a third in the Weddell Sea. In 1948, a fourth rookery was discovered by the British at Dion Island. And. in October, 1950, the first French expedition in Adélie Land found a fifth rookery of emperor penguins—at Géologie Point, longitude 140° E.. fifty miles west of their base at Port-Martin. Their successors in 1951, took a quick census of the birds that lived on this firm strip of sea ice, nestling against the coast. They counted five thousand. In 1952, the third French expedition—with which I had the honor to serve—set up a base at Géologie, so that for the first time in history a close and patient study. lasting ten months. was made of these fascinating birds. Here is what we observed during that time.



EMPERORS ARRIVE by means of two characteristic methods of locomotion. Walk is awkward because of short legs and hefty body. In tobogganing method—as fast as man's run—wings and especially feet are used to push bird along ice.

Early in March, at the end of the short summer, the last birds that breed in the Antarctic leave the rocks where they annually build their nests to fly hastily north. The islands around Géologie are deserted of wings. The first winds of winter come sweeping across the plateau from the Pole. At this time, the sea still rides clearly as far as the eye can see, the deepest of blues, becoming choppy as the wind grows stronger. But, between Rostand and Carrel and the coast, a few hundred square feet of shelf ice has stayed firm all summer. Gradually, this shelf expands to the north and west, new ice attaching itself readily to the old, and soon the whole archipelago lies locked within its grip.

At this time of uncompromising weather, in early March, something extraordinary happens. Suddenly, a dark, strongly built figure appears out of the gray swirling mist, followed by a second and then a third. The first emperors have just jumped out of the sea onto what they have come to regard as "their" ice. Instinct or a good memory has led the emperor penguins back to their rookery on the coast of Adélie Land.

A Parisian physician-turned explorer. DR. RIVOLIER served with the third French antarctic expedition in 1952, as member of special group sent to study the emperors at Géologie Point.

In reflective pose, the emperor cuts an undistinguished figure. His rather dumpy body is emphasized by the rounded back and sloping shoulders, his long beak points nearly straight ahead of him. Suddenly he raises his head: his powerful neck emerges from his shoulders and extends as though it could stretch indefinitely. He turns his beak toward the sky. In a flash, the bird has grown by nearly a foot, standing between three feet, seven and three feet, nine inches.

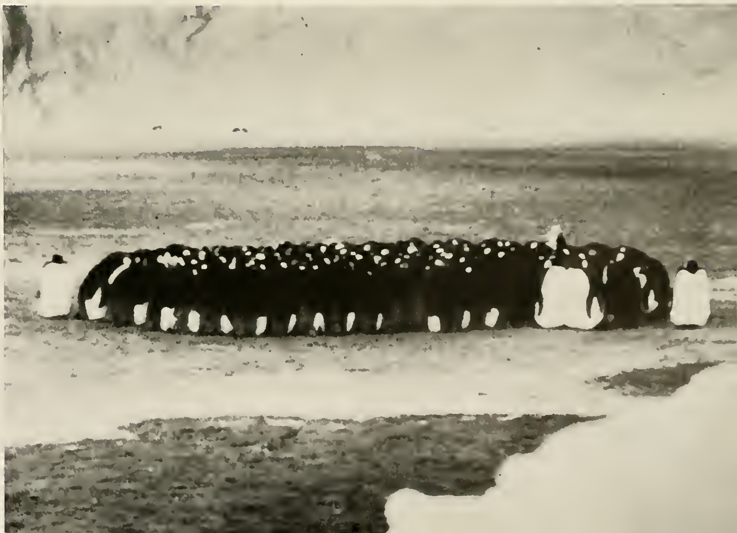
It is now possible to see that the bird's "formal dress" is not entirely black. His back and wings are midnight blue: it is the "skullcap," which reaches down to the back of the neck and extends round over the cheeks and chin, that is black. The wings are spread, showing an underside that is as white as the chest and stomach. Standing with his wings apart like this, the emperor has a span of just over a yard. His wings are, more properly, paddles. They give the impression of having been carved from wood, so free are they from fat. Here there is room for nothing except bone, muscle and sinew.

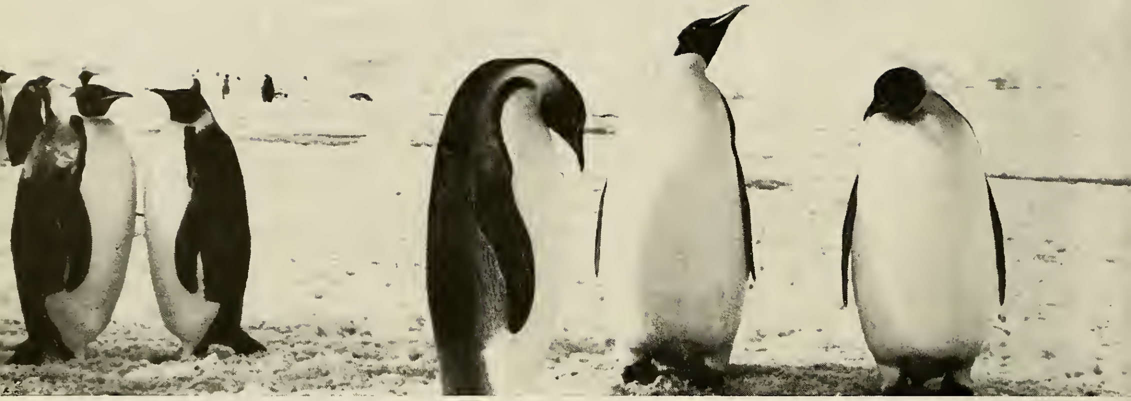
On the sides of the head and neck, the plumage runs through all the shades of gold—from yellow to copper; below the beak, on either side, there is a trimming of rose that sometimes deepens to violet.

This is the stance—the neck stretched to its full extent and wings spread—the emperor adopts immediately before throwing himself flat on his stomach to make a quick dash over the ice—a maneuver he accomplishes by calling on the full strength of his wings and clawing the ice with the nails of his feet. His muscles are powerfully developed—especially around the chest, where a quarter of the bird's total weight is lodged. In fact the pectorals, which are really the power box for the wings, grow to the amazing size of four inches. To protect him against the cold and to keep him alive during his long winter fast, the emperor has a reserve of about a dozen pounds of fat, distributed all over the body but lodged chiefly around the stomach.

When the emperor cuts down his tobogganing speed and slows to a halt, he uses his wings simply to keep his balance, relying solely on his feet to keep him going. With these, he marks the ice clearly and deeply. Whenever the direction he has chosen brings him onto a patch where the surface is uneven or broken by *sastrugi*, he pulls himself to his feet by planting his beak sharply on the ice and swinging his wings forward so that for a moment they rest there too. Then he retracts his beak, throws back his head and neck and has returned to an upright position. He now shakes himself and

Testudo formation enables penguins to pool body heat in fight against cold.





Emperor's courtship is viewed in two typical situations: couple standing motionless and face-to-face at left shows posture usual just after mate has been chosen; on right, choice is more complicated as two females vie for one male.

smooths down a few feathers with his beak before walking sedately on.

Suddenly, it occurs to him that he has walked far enough, so he comes to a standstill and remains almost motionless for hours on end, amply supported by his feet and tail. Now and again, he sways slowly backward and forward. What happens here is that the longer he stands, the more he shifts his weight back to his heels. He stiffens his tail for added support and then when he is sloping backward as far as he can, he swings gently forward, pendulum-fashion, comes to rest on his toes and once again freezes into immobility. Moments later, imperceptibly, the pendulum motion begins all over again.

The emperor allows himself plenty of time to make his toilet. His beak disappears into his plumage, looking for trouble spots of dirt or irritation. His long, agile neck makes easy work of this preening operation. Only the head presents a problem. The emperor solves it, even though his solution combines a considerable contortion with the risk of falling over. Slowly, he shifts all his weight to one foot, gripping the ice very tightly with his nails. He needs to: he is supporting sixty-five pounds on three toes. As soon as he is sure of his balance, the emperor bends his neck down as far as it will reach. Then, when his head is practically touching the ground, he raises the other foot and scratches the black feathers of his skullcap, doing the job as quickly as he can and tailoring his movements to suit his precarious position. Sometimes he falls, but he comes to no harm. Rolling over onto his stomach, he digs in with his beak and, using his wings for support, flips himself back to the vertical; returning at once to the tricky operation which brought about his tumble.

When at last he is preened, he once again strikes his reflective pose. There is a momentary activity as he spreads his wings and shakes himself and then, as though this sudden burst of energy were too much for him, he lets his head droop to one side, covers his beak with his wing and falls asleep. Sometimes the descent into sleep is announced less formally. His head simply falls forward and, for all the signs of life he shows, he might just as well be dead.

Immobility is, in fact, the most characteristic feature of the emperors' behavior. Except during a few distinct periods in their lives, the few walks they allow themselves are very brief: everything they do on land is slow and cumbersome. And with good reason: the emperor takes every conceivable step to keep out the cold and economy of movement is part of the plan. He cannot afford to generate heat simply to waste it.

On March 10, three of the birds are there; on March 11, about ten. A fortnight later the number has swelled to fifteen hundred. All this time, the ice is gaining a stronger hold, putting a girdle round the islands and spreading farther out toward the horizon. The mainland is already in its grip.

The emperors arrive from the north in small parties and emerge from the sea one after the other. The ice is five or six inches above the level of the water, but their jumps take them much higher than that. The great birds land on their stomachs and hastily pick themselves up.

Then, one of the penguins starts on his way and the others at once follow him, waddling toward the rookery in single file. New arrivals follow closely upon one another's heels, and the rate is accelerating all the time. Gradually, the special sound of the rookery increases in volume: a sound compounded of thousands of cackling voices, a sound relieved only by another, a piercing cry, which is like the blast of an out-of-tune trumpet but is in fact produced by a penguin, standing with his head tipped back and his beak open to its full extent to utter this single, terrible note.

By April 11, the population totals six thousand, but the peak is still to come. There will be new arrivals throughout the rest of the month, their trek from the open sea growing longer each day as the ice continues to expand its frontier. Already, it stretches beyond the horizon. Before long, the rookery shelters a total of ten thousand emperors.

Now, eating has become a thing of the past: the sea is too far off. The birds came here so weighted down with fat that their bellies almost touched the ice, but now the only thing they have to eat is snow. They peck at it with their beaks, throwing their heads back in order to swallow.

APRIL brings a marked restlessness: a sudden quickening of tempo invades the rookery. One emperor goes up to another and stands facing him—or her—so that there are only a few inches between them. He raises his head and extends his neck as far as it will go. He rubs his cheek against the top of first one wing and then the other; then, still without moving his feet, he bows his head very slowly, takes a deep breath, half opens his beak and starts to sing. At the end of this musical interlude, he makes no move for several seconds. Finally he straightens up and listens. If he gets no reaction, he walks a little farther on, selects another emperor and repeats the process.

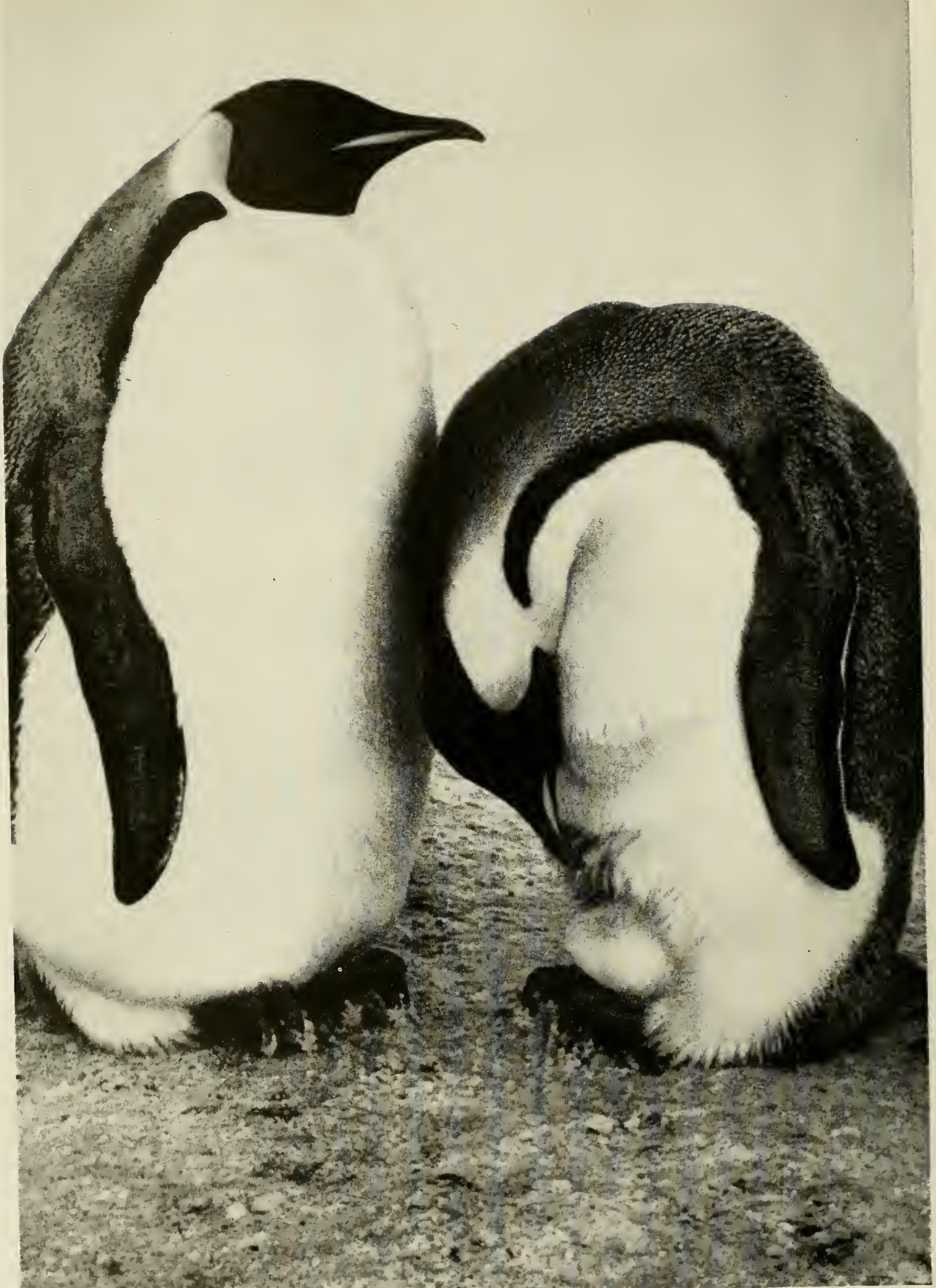
Far removed from the strident trumpet note of other days, he is now giving voice to a love song. The male starts off with a series of runs on quite a low register and then, with as much strength as he has breath for, his voice rises through a series of semitones, growing shriller as they progress, until the mating song is resolved on one sustained and vibrant note.

Not that the initiative is always taken by the male. It is considered quite in order for a female to walk slowly among the crowd, take her pick, stand directly in front of him so that there can be no doubt whom she is after and offer her proposal.

Sometimes, this first period of courtship is soon over. Sometimes, success comes only after a great deal of effort, taking four days or even longer. Sometimes, an emperor never succeeds in finding a partner. Then, he takes his place among the bachelors.

When two emperors have, in the lover's sense, found one another, they move closer together and stand face to face, without the slightest movement, for some thirty or forty seconds. Their feet are planted firmly on the ice, their bodies tilted slightly backward, their necks bulging. Suddenly

EMPEROR COUPLE remains together without any interruption during the twenty-five-day gestation period. During entire breeding season, however, mates are separated for several weeks when first female, then male leaves for ocean to feed.



Brooding the egg, female emperor carries it tucked in small fold of featherless skin at bottom of belly. Twenty-four hours at most after laying egg, female passes it to male and journeys to sea for food, breaking a two months' fast.

one of them lowers its head and breaks into a new song. The other replies, and then they touch again, sometimes with their breasts, and the duet goes on. They look as though they will never grow tired of it.

Side by side with such contented couples who have an assured future together, there is a fair sprinkling of quarrelsome trios. It is not uncommon to find two females competing for the favors of the same male. Both follow him everywhere he goes and both are quite prepared to use brute strength to settle the matter. So they go to work with beaks and wing tips while the male watches the bout with benign detachment, awaiting a decision from the females.

In early April, less and less is seen of the sun: by now, it never rises very far above the horizon and there are sixteen hours of darkness to eight of light. The temperature is falling: eighteen degrees below freezing during the day, at night it reaches twenty-seven degrees below freezing.

The emperors mold themselves into densely packed groups to defeat the night cold. With their wings flat at their sides and their shoulders pressing into one another, they form an oval-shaped testudo. All that can be seen from the outside is a row of dark backs, squeezed so tightly together that even the worst blizzard cannot deliver a deathblow. All the lovers surrender their privacy for the night and become simply part of the testudo's architecture. But next morning, after shaking themselves and preening their feathers, the emperor couples wander off again.

The sudden show of nervous energy which marks the emperors' fortnight of courtship soon fades after consummation by the couples. The birds quickly fall back into their old passive ways, awaiting the time of egg-laying, more than three weeks off. By now, the nights last eighteen hours, sentencing every living organism to an ordeal by ice and, when the brief, dull day breaks, it is made still darker by the appearance of the first blizzards.

As soon as the emperors feel such a storm approaching—and the early squalls at ground level, lashing their feet, leave no room for doubt—they gather in the same testudo formation that guards them against the cold of night. Throughout this strategic operation, there is almost complete silence within the rookery. The penguins move into formation with their usual slowness and weightiness, but inexorably and skillfully too, taking the places they must take if the testudo is to insure their common safety, thrusting themselves forward so that their shoulders are interlocked.

For hours, sometimes days, the blizzard pitches into the living statues, bringing snow and ice splintering down from the plateau to lash their exposed backs. The wind is at full strength. But in and around the testudo there is no letting up: nothing, it seems, can make the birds relax their grip. And then it is all over. The storm drops as suddenly as it started. Only a few moments ago the wind was blowing at sixty miles an hour. Now it is no more than a light breeze. The sun casts its beams almost horizontally over the ice, producing reflections of a glittering brilliance, so that now the ice offers a startling image of the testudo coming to life again. Some of the emperors have quite a thick covering of snow and their first action is to shake themselves and preen their feathers. For others, the snow clearly represents a pleasure, and in next to no time they are rolling in it and practicing something that looks like a swimmer's crawl, using their strong feet to propel themselves. The rookery releases a flood of cries and cackles that seem loud enough to fill the pale bowl of the sky.

During the night of May 5, the first eggs arrive—the females laying them directly on the ice. At daybreak, there is no sign of an egg—all seem to have vanished. But the first parents cannot contain their excitement. Each couple sings away at the top of their voices. Standing with heads on one side, they look at one another and cry aloud. Then the female bends her neck, draws in her stomach and discloses the egg—supported by her feet and tucked away in a small fold of bare skin at the lower part of her stomach. The male looks at it, gestures and breaks into song. His mate follows his example and then the egg disappears inside her thick white plumage. Then she begins the performance again, the male takes another look, and another song starts up.

The egg itself is white, but at the larger end it deepens to a light or dark fawn color. The average length is just under five inches and, at its widest point, it measures three, to three-and-a-half inches. It weighs approximately one pound.

The female develops a special way of walking to insure the egg against damage, taking very small steps and steering clear of all obstacles. Every so often, she stops and her mate—who follows a pace or two behind—is allowed another look. She draws in her stomach before she tucks the egg away into the fold again.

A few hours later, the female's actions undergo a complete change.

Birth of the chick takes place after about sixty-four days of incubation by male. Female must come back for birth, since fasting male cannot feed chick.

Spreading her wings, she tramples heavily on the ice, sways from left to right and nods her head. Her companion watches her; then he leans forward and touches the egg with his beak. The female carefully parts her feet and lets the egg roll onto the ice. The male stops it from going any farther, levers it toward him and maneuvers it between his own feet. This may take him some little time, for he has not the female's experience of putting his beak to this use; but in the end he succeeds. He lifts the egg off the ice by drawing his feet together and hides it away in the folds of his own stomach to incubate.

And now, the female begins to go for short walks. The male—egg-hobbled—does his best to keep up with her, but her walks grow more ambitious and finally he loses sight of her. And so, a day at most after laying the egg and twelve hours after handing it over to the care of her mate, the female abandons him and strikes out purposefully in the direction of the open sea.

Throughout the month of May the females will be laying their eggs and starting the journey north. Two months will pass before their mates see them again; it takes the females all of that time to cross the miles of ice, enjoy a spell of filling their stomachs, and make their way back.

SOMETIMES ALONE, sometimes in groups of two or three, the females make for the sea—now a hundred and twenty-five miles distant—with the sort of determination which nothing short of total disaster can defeat. The bergs cast a chill shadow over their route, which takes them over dunes and *sastrugi.* The way up these obstacles takes thought and effort, but the way down is simple—they slide on their stomachs. If the slope is a steep one, so much the better: it takes them that much faster the way they want to go.

This is their life throughout the weeks their outward journey takes them: each twenty-four hours sees a more-or-less set distance traveled through a labyrinth of ice, its harsh outlines softened only by the darkness and the heavy mist. The blizzard seldom lets up, but the birds' steady pace never falters. As they near the sea, they encounter an increasing number of "rivers," with irregular "banks" of ice, constantly remolded by the action of melt water. They follow the course of such streams until they come to a spot where the banks are almost touching. Then they lie down on the ice and use their tobogganing technique to go on.

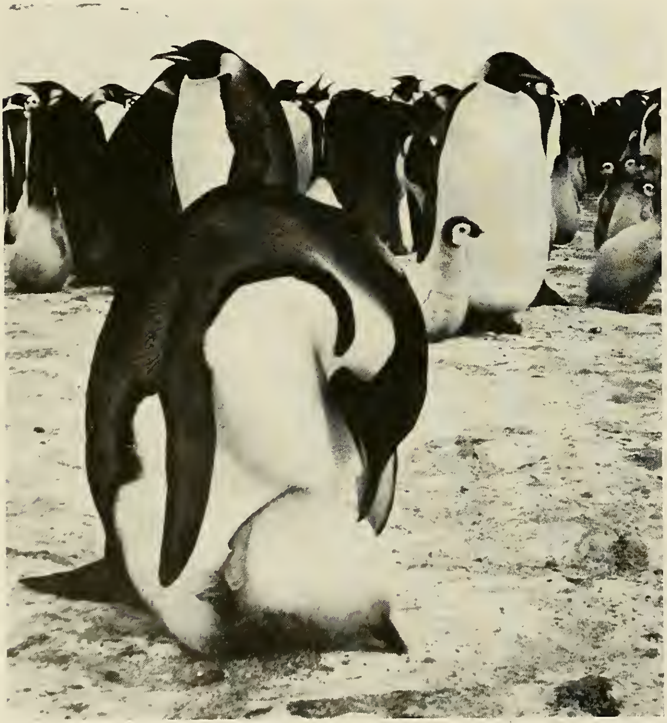
Soon, they can detect the sea not so very far ahead, its vapor partly obscuring the outlines of the ice pack. By this time, the surface is getting harder to negotiate and there are more "rivers" to cross. There are skuas in the air and others resting on gigantic pieces of floe, broken up and tossed about by the last storm. There are seals, too, lazing on the ice wherever there is water close at hand. These signs of life seem to invigorate the penguins. They begin to walk much faster and often toboggan.

The sound of the sea breaking against the pack grows stronger and stronger, and at last the moment comes when the females can satisfy their hunger. They jump into the open water without any further delay and start feeding on shellfish.

Gradually, the females regain their old strength and put on weight, until finally they reach the stage where the food they take is purely a reserve for the future. Then comes the day when they start the long journey back. The last food consumed marks the beginning of a fast that will last until spring—and this final meal is destined to be only partially their own.

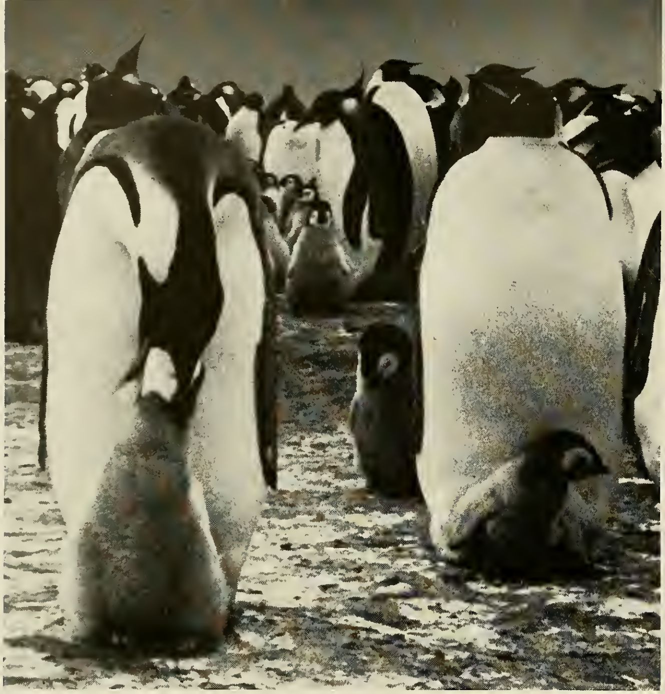
BACK AT THE ROOKERY, most of the males have been devoting themselves to the task of brooding, making sure that the egg is at all times balanced safely between their feet. They see the sun for the last time on May 21: it does not come back until July 23. Full winter is here.

Each male concerns himself with his own offspring only; but if he should lose his own and happen, shortly afterward, to find another egg abandoned on the ice, he at once possesses it and lifts it onto his feet.



SHELTERING HER YOUNG, mother bends down as chick crawls under her belly head first. Newborn birds stay in fold, resting their feet on those of mother.

MONTH-OLD, with gray down and white face marking, looks quite unlike adult.



Feeding its young, the adult emperor at left bends down to regurgitate, while chick sticks head into parent's mouth. Young feed like this for many months.

In many cases, this substitute egg has already frozen and all the long days of brooding will be in vain.

Another thing that quite often happens—especially in the early days, before the male has become used to having the egg to look after—is that the emperor throws himself onto his stomach with the idea of tobogganing. The egg falls out of its fold and onto the ice. Sometimes it smashes, but often it only cracks. The emperor returns it to the shelter in his stomach where it slowly turns bad.

Still another male may happen to let go of an egg, and it rolls away from him. The bird makes no effort to fetch it back but sets off, instead, in search of the open sea and food. The extremes of hunger tempt a few males to try to journey to the sea and look after their eggs on the way. Perhaps they get a few miles without loss, but they seldom return with their precious burden. Generally, the egg drops down the first crevasse they cross.

But most of the males take their duties very much to heart, and are prepared to defend their eggs to the very last against the dangerous curiosity of their bachelor neighbors. And, if, in spite of all precautions, the eggs escape their grasp, they chase after them as fast as they can. They remain close to one another in the testudo formation and, when the cold reaches its peak, they join into one large group — six thousand of them, nearly all with eggs, which may be intact and therefore worth all the trouble being taken, or which may, on the other hand, have rotted or frozen.

Throughout these two months of incubation (to be exact, it takes from sixty-two to sixty-four days), the males continue to go without food. May ends and June arrives with its terrible storms, its solstice, its daily quota of forty minutes of illumination no stronger than twilight. The emperors begin to look thin and their feathers have a tarnished appearance.

But the end of June sees the return of the first females. Their appearance is in sharp contrast with that of their mates. Their stomachs bulge with food, and fat is distributed all over their bodies. The moment they arrive in the rookery, they start looking for their respective males. To an untrained eye, the emperors all look alike in the dead gray light, but the females' search is thorough: the scene is a repetition of the days of courtship. The female comes to a halt in front of a male, sings to him and waits for a reply. Then she takes a few steps to another and does it all again. There are other females making the rounds of the rookery, but the male emperor can tell his mate's voice from any other, and he takes no notice of songs which are not hers. By now, the male has not eaten for a full four months.

Four-fifths of the total number of eggs laid are successfully hatched by July. The rest have fallen victim to frost or hard knocks. Hatching takes forty-eight hours and during these two days the female emperor—back on the job—hardly moves. She knows the time has come by the feeling of life beneath her—a slight shaking, the chick's first attempt to break out. Finally the shell *does* break and the baby lies across his mother's feet, under the protective fold of her warm skin.

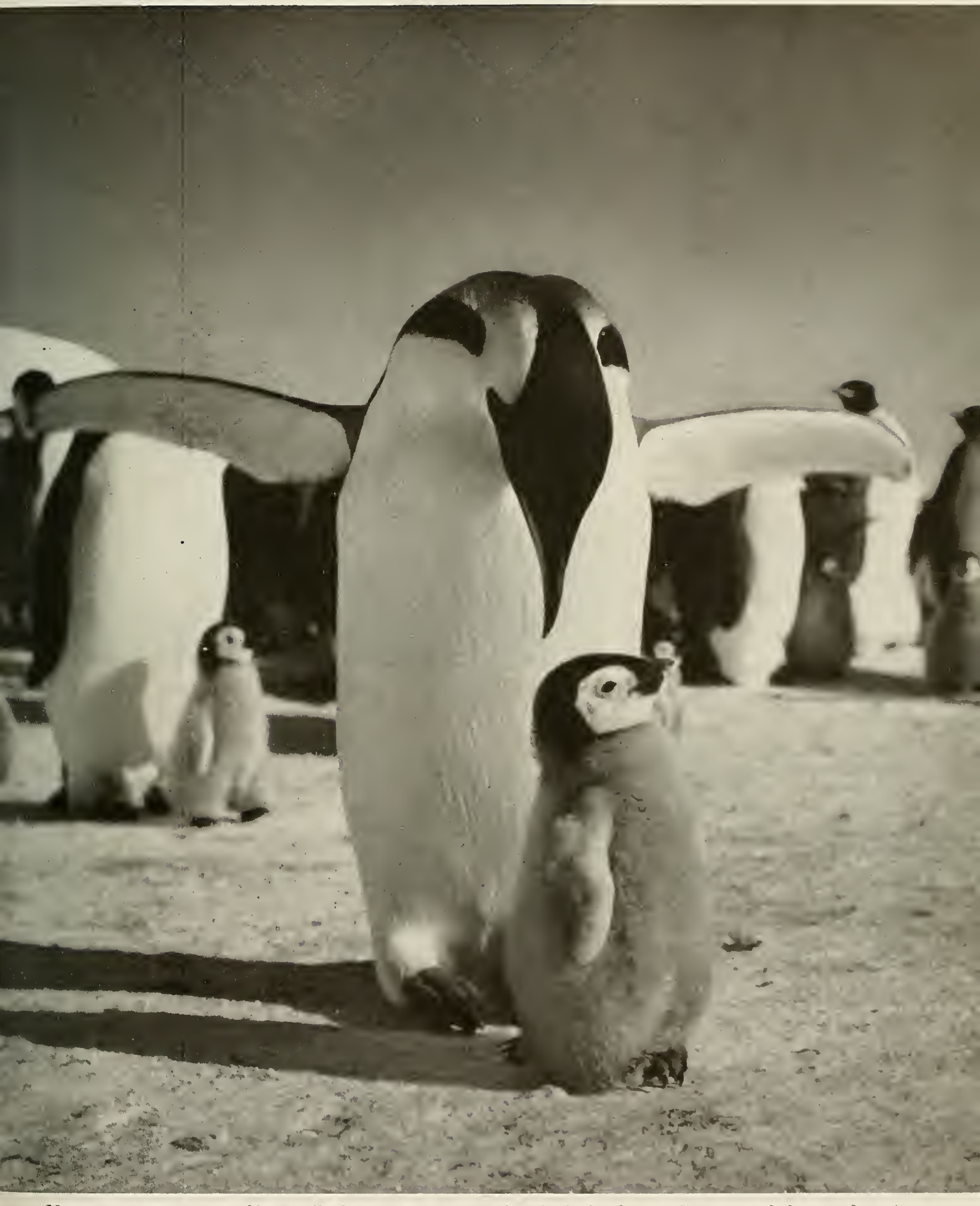
At the time of his birth the young bird is about six inches tall—a small pyramid of gray, woolly, beautifully soft down. At first the gray is uniformly light, but it grows gradually darker at the top and on the back of the head. Two white circles around the eyes make him look rather like a young owl.

The chick soon starts to sing—a series of weak chirps at first, but his voice quickly grows stronger. Slowly he pulls himself into an upright position, placing his feet on those of his mother, so. that, wherever she goes, he goes too—his gray, fragile little limbs incongruously trying to keep pace with his mother's.

When the mother decides they both need variety, she bends her head and releases the chick for a few moments from his warm skin-lined cell. She watches him for a time. Then, again, she tucks him away from the cold.

The mother starts to feed her chick almost as soon as he is hatched. She has brought back well over two pounds of food in her stomach, so she opens her beak wide enough for him to insert the whole of his head, and feeds him by the simple process of regurgitation. He stretches as far as he can on his weak legs, anxious not to miss a scrap, and very soon gathers strength and gains in weight.

But it often happens that a chick is born before his mother's return from the sea. Then, however appealing his cries, the father has nothing to give him to eat. So, many newborn chicks die of starvation annually.



Maturing emperor is now able to walk about on its own. Young bird still remains by parents, however, dependent on them for food and too weak to cope with the rugged terrain. Molting has not yet begun—the chick still wears fuzzy down.

THE CHICKS are kept under strict surveillance—and so they need to be. Almost as soon as they can walk, they want to wander about the rookery and investigate the whole of this strip of sea ice—the only solid footing, after all, their feet will ever know. To their weak cries of hunger and weak cries of repletion, weak cries of sheer panic are intermittently added. For, when a chick does succeed in getting away from his mother and wandering about among the other adults, he very soon finds himself receiving more attention than he bargained for.

Every emperor in the place who has failed to find himself a mate comes chasing after him and tries to adopt him. In a flash, the chick disappears beneath a horde of adults, all cackling away fiercely at one another and trying to beat each other off with their wings in order to assert their personal mastery. In the midst of all this scuffle, the chick can be heard crying for his mother. If he is lucky enough not to die from being buffeted from one adult to another, his most likely method of escape is to be thrown clear of the melee when two, much heavier bodies collide. He rises, badly shaken, his mother administers a few corrective nudges with her beak, he climbs back onto her feet and is soon a safe distance from the battlefield.

Later on, the bachelors and spinsters become resigned to their lonely status and give up trying to appropriate stray chicks. They return to their earlier placidity, and the quiet chirping all round them no longer has the power to stir their emotions. They turn from the rookery and head for the open, antarctic sea.

As the chicks grow bigger and stronger, they tend to lose their respect for their mothers' beaks. The urge to wander is there, and in twos and threes they *do* wander, completely at the mercy of the terrible conditions in which they were born. All the difficulties of the terrain are multiplied a hundred times by their weakness and inexperience: for them, a small dune might just as well be the highest mountain in the world and it takes almost nothing to send them sprawling on the ice. They are still too young to walk straight and the imprints they leave in the snow are reminiscent of a drunk's journey home. They move with their bodies hunched forward, thrusting their heads inquisitively toward anything which confounds or intrigues them. Sometimes, other adults take a poor view of their excursions and give them a sharp rap on the head with their beaks. The chicks make their getaway as best they can, their necks stiff with fear, stumbling and quite often falling, their small eyes, peering out from the absurd white rims, rarely free of an expression of something like bewilderment.

NEW PHASE in young emperors' growth begins as families break up and chicks are grouped into nurseries, supervised by adult penguins. In the winter storms,

IN SEPTEMBER, the male emperors return from their two months' absence, and they in their turn make the rounds of the rookery, going through the old procedure of singing and listening to locate their mates and children. The chicks regard their plump and weighty fathers as walking food cupboards: they at once fasten onto them with the blatant greed that only true hunger can excuse.

Soon there is a new social development in the life of the rookery. For the first time since the mating season, the emperors begin to act as a community and not simply as a number of individual couples and — later — families. The chicks are now assembled in a number of "nurseries," watched over by a few adults. When a storm looks to be breaking, the young birds are quickly surrounded by a rampart of fully grown bodies which, if the plan succeeds, will prevent them from freezing to death. But the chick who strays from the nursery has no hope of survival. Bowled along and buffeted by the wind, he may later be found half a mile from the place where he was last seen. He is swept uphill a great deal faster than he can climb, bounced down steep slopes until most of his bones are broken and finally deposited somewhere to freeze.

Each storm brings its heavy quota of dead chicks. Fifty is a fair average; a hundred is nothing out of the ordinary. If the score is still higher, the skuas are well content. The annual sacrifice to the whims of the Antarctic is a heavy one: if the chicks are not

offspring are shielded by rampart of adults. Even so, more than a hundred may die in single storm, and only one-fourth of newborn survive until spring.

killed off by hunger, cold or storms, there is the risk of disease—a particularly terrible one that paralyzes them before it allows them to die. The odds are heavy: only a quarter of the number born live to see the spring.

September gives place to October, and an increasing number of adults, both male and female, abandon their young for the time being and leave for the sea. They do not have so far to go, now, and the "rivers" in the ice are broad enough for the seals to jump in for a swim.

This move of the rookery adults has a purpose other than feeding. For the adults will now meet the yearling emperors—those who were born at the rookery last year and who now, toward the end of November, are returning to the place of their birth.

Back in March, when their parents came on to Géologie, the yearling emperors did not attempt the same full journey. No one knows for certain where they have spent the intervening months, but it was probably somewhere much farther north—right at the other end of the pack, where the climate is mild. And now they have come to the rookery to molt—shedding their early plumage—and develop the signs of their maturity, on ice that will give them a sure footing, however warm the spring. When they are molting they cannot swim: and if they had stayed on any longer in the north, the ice might well have broken up and forced them to attempt the impossible. Another consequence of their inability to swim while molting is that they cannot fish for food, and so they are faced with a fast of twenty days—an introduction, as it were, to this habit. For, next year, as breeding adults, they will have to fast for a far longer period. But they clearly do not enjoy the experience: they stand as still as their shivering will allow, their bodies too thin, their plumage looking definitely moth-eaten, and altogether they show up poorly compared with their seniors, who have regained their old solidity.

As for this year's chicks, by now they have grown until they reach their parent's shoulders, even though they are still fed by their parents. Their fleecy, light-gray down has kept pace with the growth of their bones, but it has become so dirty and bedraggled that it has rather the appearance of an old carpet. The molting of the chicks begins not long after this. The youngsters lose their soft down and move from childhood into adolescence. In no time at all, it seems, they are wearing the same feathers as their parents, in the same shades of white, midnight blue and black. All they lack is that golden patch on the neck and a greater precision in the shape of the beak. They are still comparatively small and their present strength is only a fraction of what it will become, but at least they can swim and will soon be able to try their hand at fishing.

By late December, the returning sea is scarcely twelve miles away. The ice along the glacier has already broken up, creating canals that link lakes of some size to the ocean beyond. The emperors—adults, yearlings and chicks—file off to the nearest water, climb to the top of the overhanging cliffs and dive in, one after another. The sea is the place where they really come into their own. Their bodies, which never seemed anything but big and awkward when they were on the ice, are now light, quick and wonderfully maneuverable. They are literally in their proper element.

Yet the mood is soon broken. They have an enemy here, too, as deadly as any they have faced on the ice. There is a shark on the prowl and, in a flash, merriment turns to panic. They swim back to the bank as fast as they can, use their wings to jump clear and belly-flop onto the ice. One of them is missing. The shark was too quick for him and crushes him in his enormous jaws.

The decision as to whether the birds should risk diving again is left entirely to the leader, who stands out in front of the rest. Once he decides to jump, the others will follow suit. But his hesitation has to be seen to be believed. He stands there, nodding and shaking his head, as though his thought processes were slowed down by the knowledge that his followers are all waiting for him to give the signal. But if one of the others tries to usurp the leader's position, this hesitant thinker suddenly becomes a very angry and very powerful emperor, who refuses to be supplanted and makes this clear to the intruder by hitting out furiously with his wings. Yet, immediately after, he sinks back into his earlier, apparent indecision.

THE emperors enjoy their spell of fishing and swimming; and then the time comes when they leave Géologie for the two summer months, on a journey that no human has yet traced. By now, the sea has arrived: the waves lap against the very edge of the rookery. As far as the horizon, blocks of ice seem to be drifting at will, but in fact the current is carrying them slowly westward. The rookery ice breaks up in a series of groans and cracks, some of the pieces colliding as they drift away and break once again.

Some of the larger blocks carry a heavy load of emperors, which are shipped along by waves. They are saying goodbye to Géologie until next year, and the recent time for playing is over. They have as much water as they want now, but they are no longer tempted to jump in. They stand pressed closely against one another, not making a movement. It is the end of the short but welcome holiday which started only after the chicks had lost their down and learned to swim.

For most of their ten months' stay, the Pole has done its best to kill them, but now it chooses to smile on them. There is a certain cruelty in the smile, however, for the emperors will be back again in March and at the mercy of the Antarctic for another ten months. The great birds will again pay the price—a heavy one, indeed—for this grim continent's hospitality.

Away they go; their crude rafts of ice may be taking them temporarily out of harm's way, but they are only on parole, for habit and instinct will bring them back when next the sea freezes over and the winter storms come howling across the plateau. Each year their numbers dwindle.

From the pairs that manage to breed, there will come only the one egg each year; a fifth of these eggs do not survive the rigors of antarctic incubation; finally, the chicks who are still alive the following spring will represent only a fifth of all the eggs laid in the rookery. The emperors are dying out. Fewer leave and fewer return each year: finally, it seems plain, there will be no emperor penguins.

WINTER'S END is marked by breaking of sea ice which had covered Géologie Bay, forming breeding ground. In May, when eggs are hatched, the sea is over a

hundred miles away; by late December it laps the rookery. Emperor colony—adults, year-olds and fledglings—will then take to the sea, for a destination that has still to be discovered. They will return to breed again next March.

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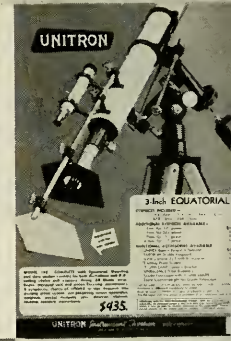
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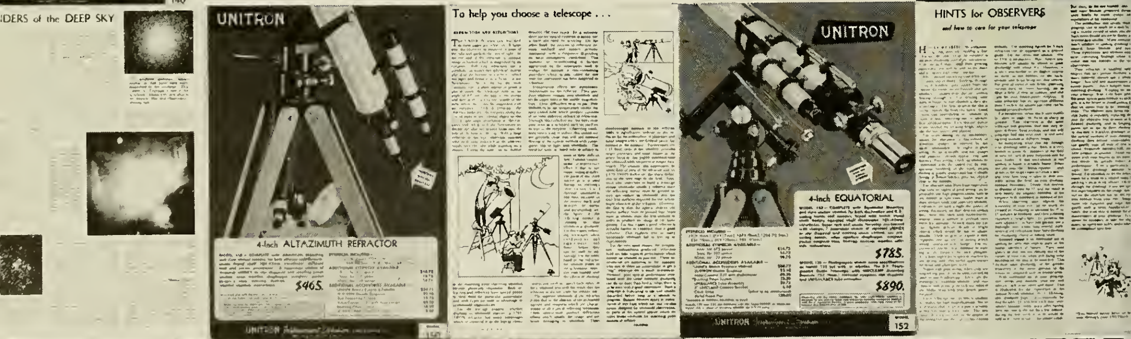
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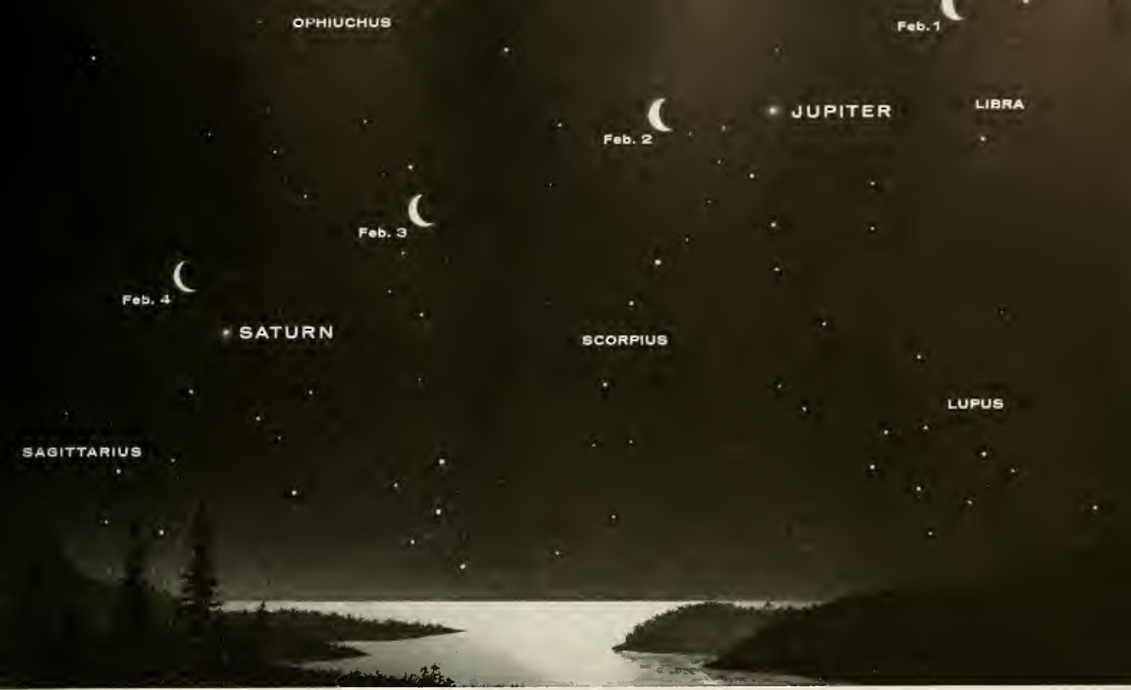


THE WANING MOON in the predawn sky, during the first four days of February, serves as a pointer to help locate two of the four naked eye planets—Saturn and Jupiter—that are visible this month. Best time: 5:30 to 6:00 A.M.

SKY REPORTER

By
Henry M. Neely

FOUR OF THE NAKED EYE PLANETS are available for sky watchers this month. MERCURY is the only one that will not be visible (see the note in the Sky Schedule. *below*. for February 14. which explains the reason).

VENUS is conspicuous over the horizon between west and southwest as the dusk deepens in the evenings. It will be seen constantly higher and more brilliant until well into the summer. This month, VENUS is passing through the constellation of AQUARIUS and into PISCES.

MARS is still a brilliant object as darkness falls. It is shown on this month's roll-around map. MARS does not set until well after midnight—about 2:00 A.M. the first half of the month and about 1:30 toward month's end. This ruddy planet will again offer visual proof of its eastward motion against the background of the distant stars. The map shows that. on February 1. MARS will be seen below the PLEIADES. During the first week. it will be passing close to that cluster and. by midmonth. it will be above the PLEIADES. At month's end. it will be almost exactly as high as the bright star. ALDEBARAN.

JUPITER and SATURN are now entering our sky picture, but they are for dawn observers who are outdoors between 5:30 and 6:00 A.M. They are shown in the illustration. *above*. which gives their positions among the stars as the viewer faces between southeast and south. On the first four mornings of the month. the crescent of the waning moon will help the observer to identify them.

Below, arranged in almanac fashion. is the month's Sky Schedule, listing the interesting events that are of importance to the confirmed stargazer.

FEBRUARY 1 to 9:

These are the best nights for binocular or telescopic—or even naked eye—observation of a famous star cluster called PRAESEPE, sometimes referred to as The Beehive or The Manger. This faint. misty spot of light is in CANCER and can be easily located by its position relative to the bright stars, CASTOR and POLLUX. almost overhead at the times for using this month's map. PRAESEPE is so faint that it cannot be seen if there is a bright moon in the sky and after first quarter. on February 15. there will be too much moonlight until February 24. when the moon will be too low to interfere.

In ancient days. PRAESEPE was considered an infallible weather indicator. If it could be clearly seen and appeared to sparkle. clear weather was indicated. If it was almost or entirely invisible. rain was expected.

"Shooting star" enthusiasts have a shower scheduled from February 5 to 10. with maximum on February 9. The meteors seem to radiate from around the very brilliant star CAPELLA in AURIGA. Roll this month's map to bring the west horizon to the bottom. and AURIGA will be found not far from overhead. This shower usually averages about twelve meteors an hour. After 2:00 A.M.. AURIGA will be too far down in the northwest to be seen easily.

MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this monthly feature for NATURAL HISTORY.

On February 9, brilliant VENUS and the thin crescent of the two-day-old moon make a striking picture over the horizon between west and southwest about 6:00 P.M. as dusk deepens. They will also be worth observing on February 10, when the moon will be directly above VENUS but twice as high over the horizon.

FEBRUARY 10 to 18:

MERCURY reaches "superior conjunction" on February 14—which means that it has circled around to the far side of the sun and is in line with the sun—out of view.

The moon, in its first quarter, and brilliant MARS will attract the attention of many casual observers who have not yet become interested in sky-watching. They will be quite close together on February 15, almost directly over the south, as evening twilight ends about 6:30 P.M. Closest approach is a few minutes after midnight (EST) but, by that time, the two will have moved down the western sky, to between 15° and 20° above the horizon.

FEBRUARY 19 to 28:

Readers who have not yet located JUPITER and SATURN by means of the moon in the predawn sky now have an opportunity to use the moon, nearing last quarter, as a pointer once again. On February 28, the moon will be only slightly to the right of the position shown in the illustration (p. 83) for February 1. On March 1, it will be slightly to the right of the February 2 position on the map. The best time for these month-end dates is about 5:15 A.M. Again face between southeast and south.

BEGINNERS who find star maps puzzling, may use the moon as a helpful guide in the use of the roll-around map from February 13 to 24, always being careful to observe the timetable for the map.

For February 13, 14 and 15, roll the map to bring "west" to the bottom. On February 13 and 14, the fairly bright stars HAMAL and SHERATAN, in ARIES, will be to the right of the moon and it should be easy to find the star MENKAR, in CETUS, to the left. Farther to the right of HAMAL and SHERATAN, almost southwest, a string of fairly bright stars leads almost vertically upward through MIRACH and ALMACH, in ANDROMEDA, to MIRFAK, in PERSEUS, and on up to brilliant CAPELLA, not far from overhead.

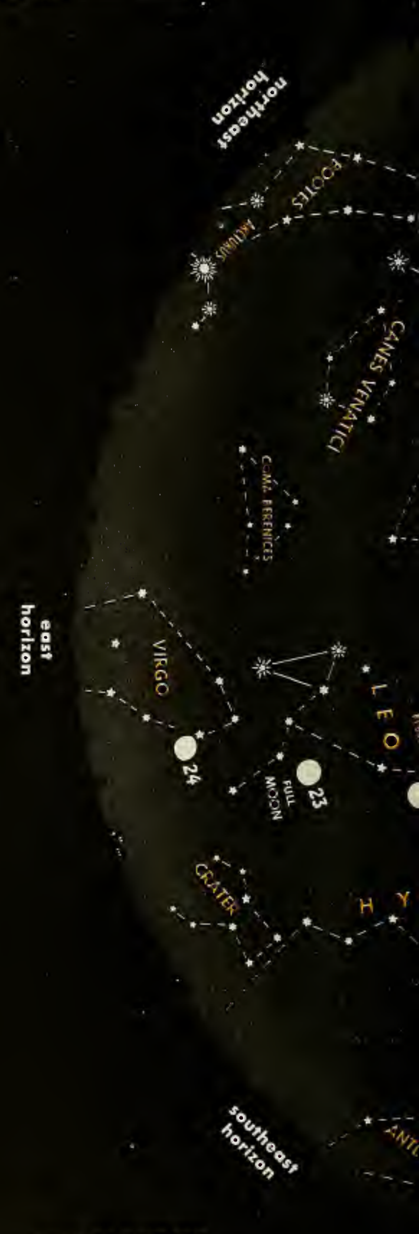
On February 16, 17 and 18, the moon will be bright enough to dim out the fainter stars around it (bring "southwest" to the bottom) but the great figure of ORION will stand out clearly—to the left and lower than the moon. To the left of ORION, almost directly over the south, gleaming SIRIUS, the Greater Dog Star, cannot be missed.

February 18, 19 and 20, (map, as printed here, with "south" at bottom) the moon observer will be facing SIRIUS and should look above it, to the left, and find very bright PROCYON, the Lesser Dog Star. Higher than the moon, almost overhead, will be The Twins, CASTOR and POLLUX.

After February 20, the bright moon (which is full the morning of February 23) will make stargazing virtually impossible. By February 24 (bring "east" to the bottom), the moon will be so low that there should be a chance of tracing out the famous figure of the Sickle in LEO.

THE MOON'S PHASES

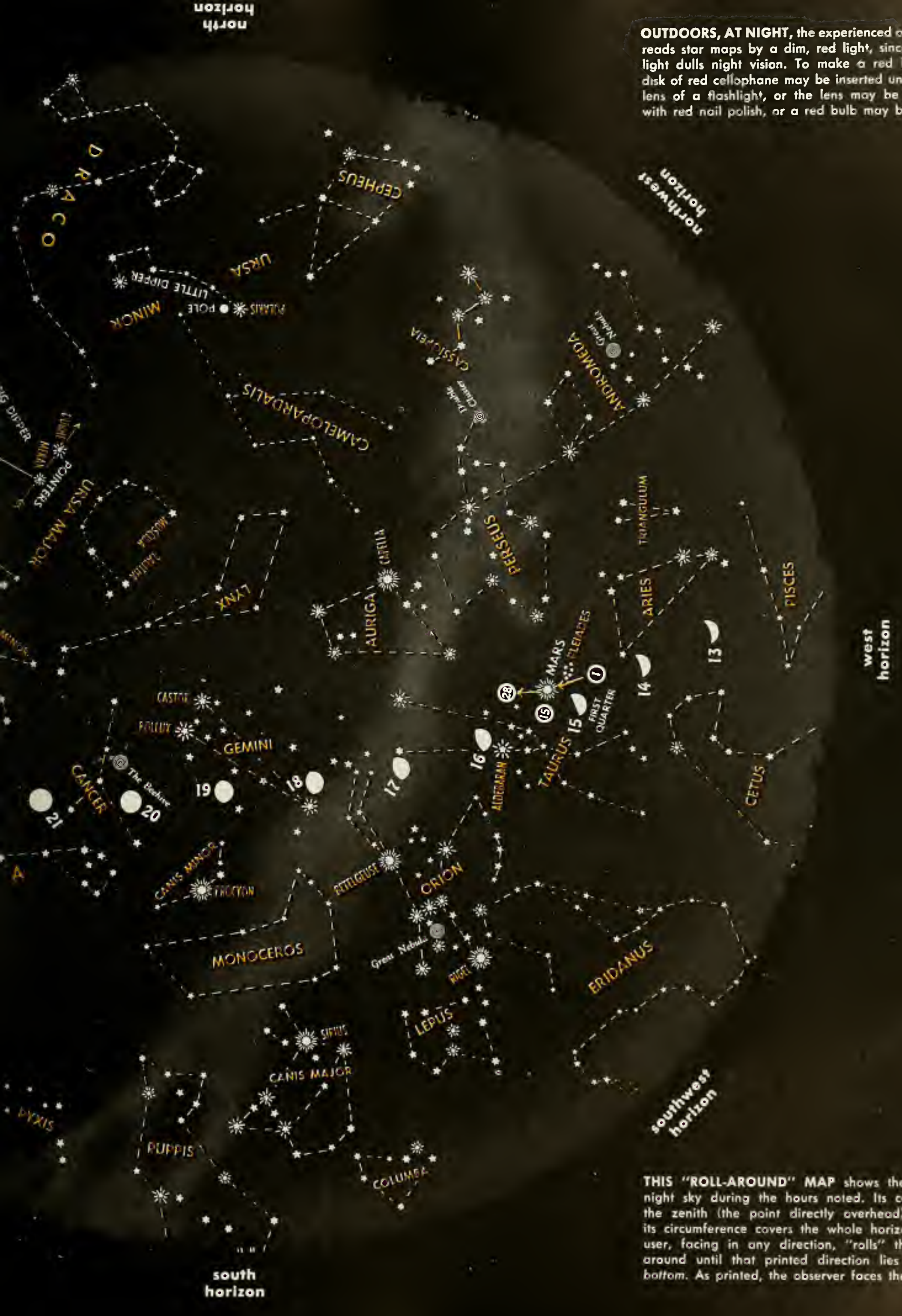
New Moon	February 7
First Quarter	February 15
Full Moon	February 23
Last Quarter	March 1



FEBRUARY TIMETABLE

First week	9:50 to 10:50 P.M.
Second week	9:25 to 10:25 P.M.
Third week	8:55 to 9:55 P.M.
Last week	8:30 to 9:30 P.M.

OUTDOORS, AT NIGHT, the experienced observer reads star maps by a dim, red light, since white light dulls night vision. To make a red light, a disk of red cellophane may be inserted under the lens of a flashlight, or the lens may be coated with red nail polish, or a red bulb may be used.


north horizon
northwest horizon
west horizon
southwest horizon
south horizon
DRACO
CEPHEUS
URSA MINOR
LITTLE DIPPER
POLE
POLARIS
CASSIOPEIA
Great Nebula
ANDROMEDA
CAMELOPARDALIS
Double Cluster
BIG DIPPER
ALCOR
MIZAR
POINTERS
URSA MAJOR
MUSCIDA
TALITHA
LYNX
CAPELLA
AURIGA
PERSEUS
TRIANGULUM
ARIES
PISCES
PLEIADES
MARS
1
28
15
FIRST QUARTER
14
13
CASTOR
POLLUX
GEMINI
The Beehive
CANCER
21
20
19
18
17
16
ALDEBARAN
TAURUS
CETUS
CANIS MINOR
PROCYON
BETELGEUSE
ORION
MONOCEROS
Great Nebula
RIGEL
ERIDANUS
LEPUS
SIRIUS
CANIS MAJOR
PYXIS
PUPPIS
COLUMBA

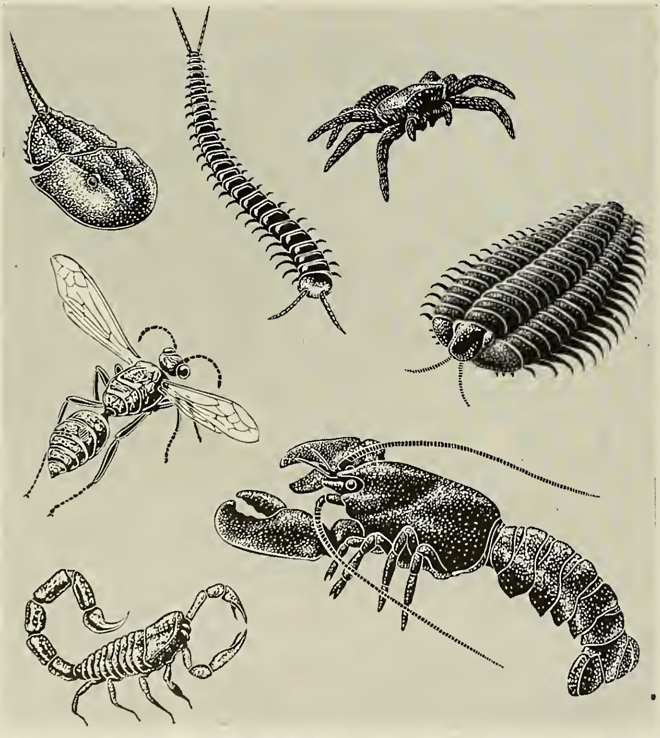
THIS "ROLL-AROUND" MAP shows the entire night sky during the hours noted. Its center is the zenith (the point directly overhead), while its circumference covers the whole horizon. The user, facing in any direction, "rolls" the map around until that printed direction lies at the *bottom*. As printed, the observer faces the south.

NEW LIGHT ON THE CRUSTACEANS

A tiny creature recently discovered on the bottom of Long Island Sound, *Hutchinsoniella macracantha,* seems to be both "living fossil" and "missing link"

By Howard L. Sanders

Drawings by Kenneth Gosner

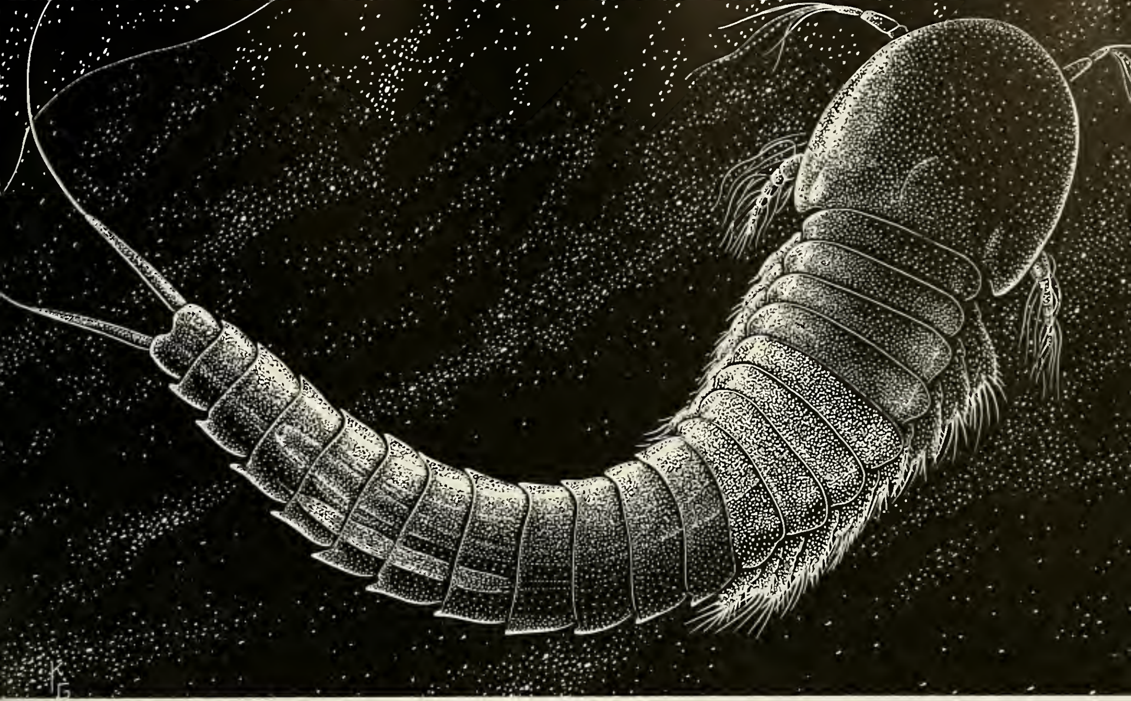


Arthropod relatives of sea and land include, on *top*, from *left*: a horseshoe crab, centipede, spider and trilobite; at *bottom*: wasp, scorpion and lobster.

Most biologists would agree that, after almost two hundred years' systematic collecting of animals in every imaginable corner of the earth, very few *major* morphological types can have eluded the taxonomists, and that such unknown major forms as may exist are to be discovered, in all probability, among the inhabitants of the relatively inaccessible great depths of the oceans.

This probability has been very recently verified by the discovery of the new phylum, Pogonophora, and of *Neopilina* (Natural History, March, 1958); but in 1954, another taxonomic find was made—yet this time, it occurred, not at the great depths of the open sea, but on the bottom of the hardly inaccessible waters of Long Island Sound. This new animal proved to be a rather peculiar crustacean.

The Crustaceans—which include the crabs and lobsters as their best-known representatives—are often viewed as the aquatic counterparts of the terrestrial insects. Both groups, together with the spiders, millipedes, centipedes—and the long extinct trilobites and eurypterids of Paleozoic



“Hutchinsoniella macracantha” is seen here in a greatly enlarged drawing — it is actually less than a tenth of an inch long. Subclass name, Cephalocarida, comes from shield-like head; species *macracantha* refers to long tail spines.

times—belong to the phylum Arthropoda. They are animals with segmented legs and a hard, chitinous exoskeleton. The single phylum Arthropoda contains *more* animal species than the combined total of the rest of the animal kingdom.

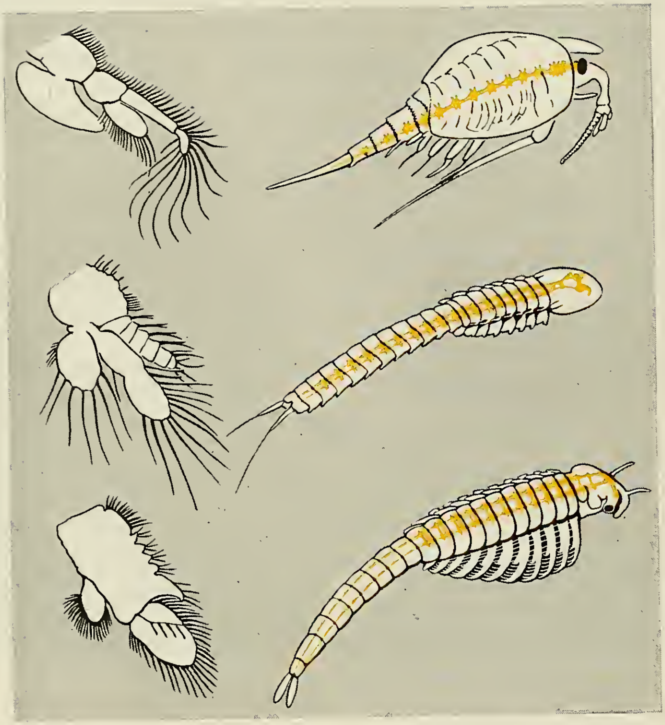
The class Crustacea, within this phylum, is divided into six major categories formally known as subclasses. And because each subclass constitutes a sharply demarked unit without intermediate forms, the relationships of these subclasses to one another and the history of their origin are poorly understood. For this reason, the theories that have been proposed to explain crustacean evolution are speculative and controversial.

We are all familiar with crabs and lobsters, and perhaps less so with sand fleas and sow bugs. These are all representatives of a single crustacean subclass, the Malacostraca. Copepods, those minute organisms that constitute a large part of the zooplankton found in both fresh and salt water, form another crustacean subclass, called, not surprisingly, the Copepoda. The highly modified barnacles, found encrusted on rocks at low tide, represent still another group, the Cirripedia. A fourth category — the Ostracoda—includes the small, shelled crustaceans which are reminiscent of tiny clams. The brine shrimp, the fairy shrimp and *Daphnia*, the water flea—often possessing a large number of body segments—are members of the fifth subclass, the Branchiopoda. The sixth subclass, the Mystacocarida, discovered as recently as 1942, are a small group of crustaceans that live in the spaces between sand grains in intertidal beaches.

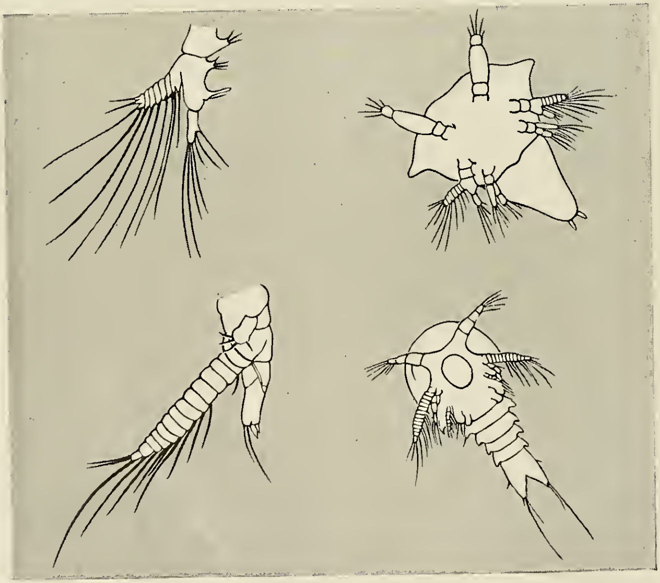
In the process of analyzing samples of bottom-dwelling animals from Long Island Sound in 1954, I came upon a number of small, elongated, somewhat transparent crustaceans. These minute creatures, hardly a tenth of an inch in length, were strikingly different from any of the crustaceans with which I was familiar, for a cursory examination revealed a large number of body segments whose presence excluded the animal from all the crustacean subclasses except the Branchiopoda. Yet, the bifurcated (or biramous) trunk limbs—each with an inner and an outer branch—were markedly different from the leaflike structures characteristic of that group. It seemed possible, then, that this organism represented a new taxonomic type.

Subsequently, more detailed studies of the tiny creature's morphology have verified this initial conjecture, leading me to erect a seventh crustacean subclass, the Cephalocarida, to include this animal—which I have named *Hutchinsoniella macracantha*, in honor of Professor G. E. Hutchinson, of Yale University. As taxonomic nomenclature may appear puzzling to the uninitiated, it should perhaps be said that these two terms were not chosen at random. The subclass name, Cephalocarida, stems from the fact that these animals have a covering or carapace over the head that is reminiscent of a shield; hence the term “head shield.” The word macracantha, in turn, refers to the extremely “long spines,” pointing backward on the animal's telson, or tail.

Even more exciting than the creature's uniqueness, however, were indications that it shared certain morphological characteristics with the more primitive members of most of the



"MISSING LINK" role is seen through *Hutchinsoniella*'s similarity to other crustacea. *Above*, the number of body segments and paired ventral nerve cord relate creature (*center*) to branchiopods (*bottom*), while the limb form links it to Malacostraca (*top*). Naupliar stage, *below*, shows likeness between head and antenna in *Hutchinsoniella* (*bottom*) and in the barnacle (*top*).



Now at Woods Hole Oceanographic Institution, DR. SANDERS is studying animals that inhabit the ocean floor.

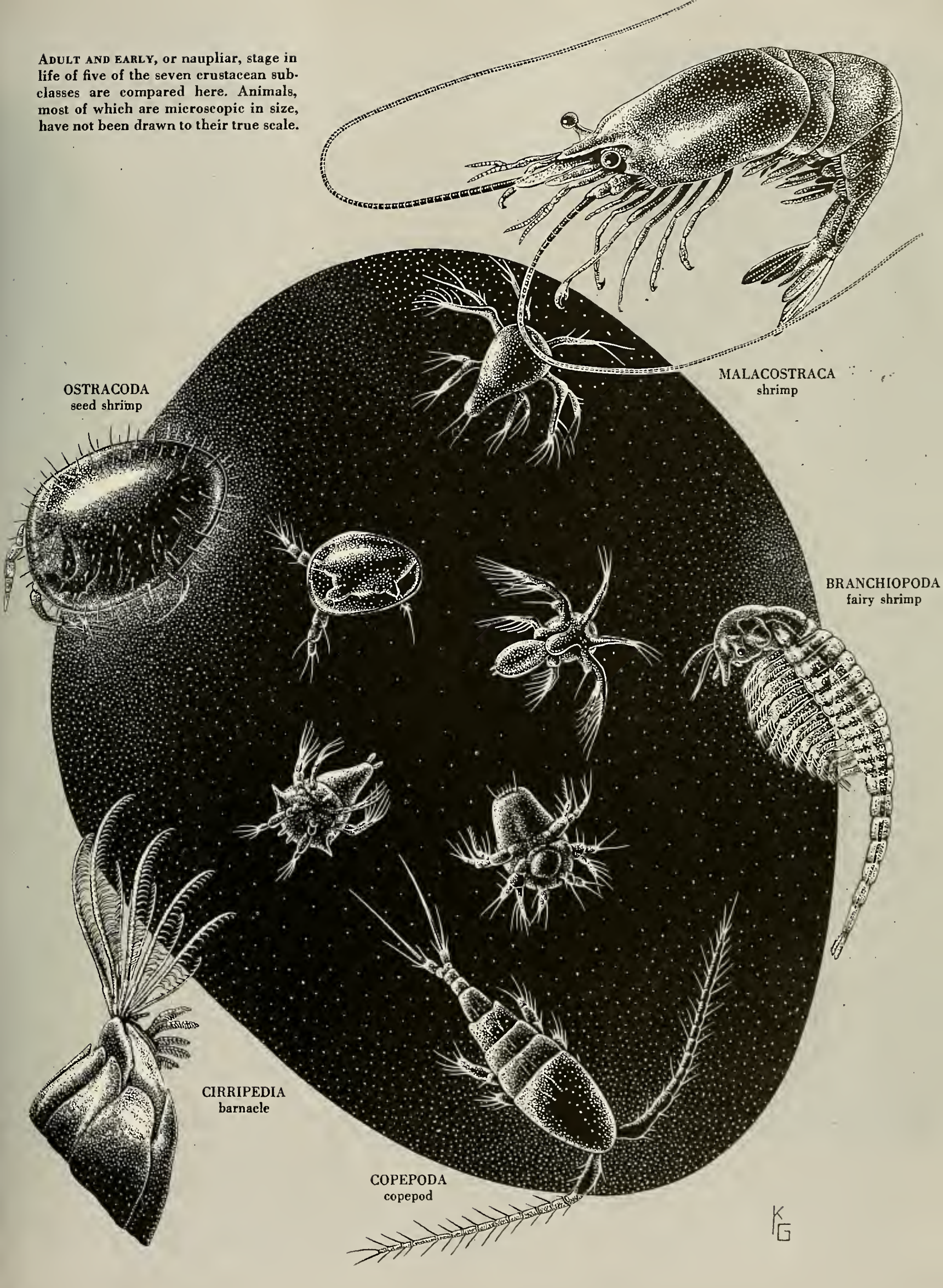
other crustacean subclasses—for, as it was pointed out earlier, the absence of such suggestive. intermediate forms has in the past been the chief barrier to fruitful speculation regarding the evolutionary history of the crustaceans. Now, in *Hutchinsoniella*, the trunk limbs seemed most similar to those found in the Leptostraca, a primitive order of the subclass Malacostraca; yet the head appendages are almost identical to the same structures in the more generalized or larval representatives of the copepods, barnacles and ostracods. Finally, the new animal's numerous body segments and the paired ventral nerve cord are uniquely shared with branchiopods. What all these resemblances seem to suggest, then, is that *Hutchinsoniella* might be a long-sought-after "missing link."

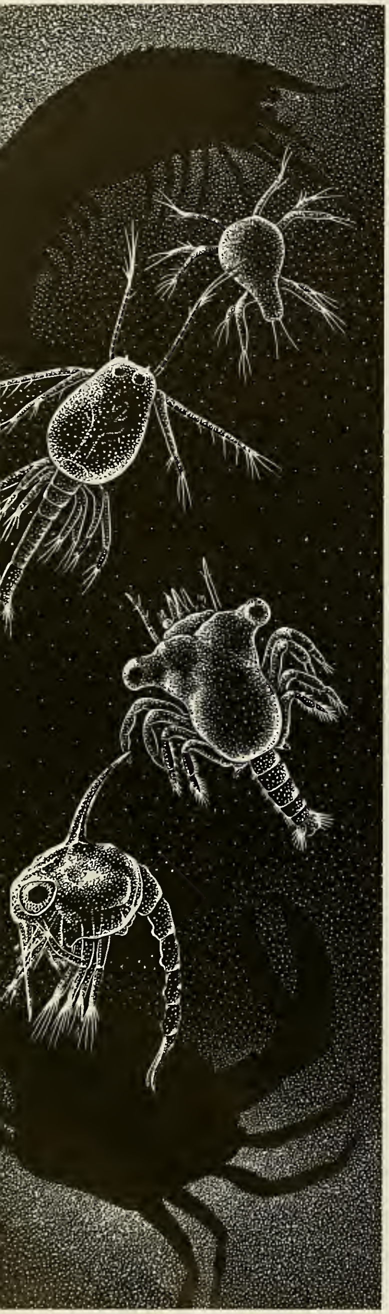
THERE is circumstantial evidence for such a surmise in the fact that the *adult Hutchinsoniella* has taxonomic features present only in the *early* (or naupliar) stages of the development of many other crustaceans. For example, *Hutchinsoniella* retains the so-called masticatory process—a small extension at the base of the second antenna, used for feeding—until a late juvenile stage. This same structure is found only in the naupliar stage of other crustaceans. Furthermore, the median or so-called "naupliar" eye in the adult *Hutchinsoniella* is on the ventral rather than dorsal surface, which agrees with its position as it is found in the nauplius of other crustaceans.

In fact, it is tempting to regard our *Hutchinsoniella* as merely an elongated, adult nauplius. From such "ancestral" stock, it would be possible to derive the other crustacean subclasses by the process known as neoteny. In this process an organism becomes sexually mature at an earlier developmental, or larval, stage – the later stages are sloughed off and are forever lost from the genetic constitution of the species. Unencumbered by the more specialized adult characteristics, the organism becomes genetically plastic and can respond readily to its environment.

Such a hypothesis envisions di-

ADULT AND EARLY, or naupliar, stage in life of five of the seven crustacean subclasses are compared here. Animals, most of which are microscopic in size, have not been drawn to their true scale.


MALACOSTRACA
shrimp
OSTRACODA
seed shrimp
BRANCHIOPODA
fairy shrimp
CIRRIPEDIA
barnacle
COPEPODA
copepod



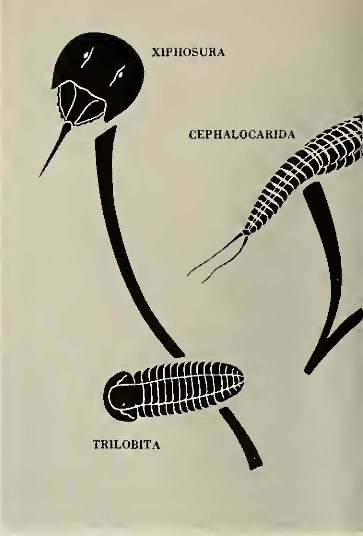
Larval stages of shrimp *(top)* and of crab *(bottom)* reveal certain features lacking in adults but found in adult *Hutchinsoniella* – which thus seems to represent ancestral crustacean stock.

verging evolutionary patterns, initiated perhaps several times as a response to neoteny, eventually resulting in the formation of a number of the present-day crustacean subclasses. The scheme seems to make sense, since only the early larval or naupliar stages are common to all the crustacean subclasses, while there are few morphological similarities among them in the later stages, except those which are shared with the new subclass, the Cephalocarida.

What can we learn from the fossil record to gauge the relative significance of this new crustacean find? Crustacean remains from the Paleozoic period—approximately 250–500 million years ago—are few. Of those fossils that are definitely demonstrated as crustaceans, none appears to be as "primitive" as this small, contemporary cephalocarid from Long Island Sound. Apparently, the closest fossil relative of *Hutchinsoniella* is the wonderfully preserved fossil from the Rhynie Chert deposits of Scotland, known as *Lepidocaris rhyniensis,* which lived about 300 million years ago. Yet this mid-Devonian relation—already an unmistakable branchiopod with the reduced head appendages characteristic of this subclass—is more specialized than is our morphologically conservative *Hutchinsoniella.* Rather, using the trunk appendages of the Rhynie Chert crustacean as an *intermediary,* it seems perfectly possible to derive both types of crustacean trunk limbs—the biramous and foliaceous—from the cephalocarid appendage, as we find it today on *Hutchinsoniella.*

Thus, the evidence from three sources—comparative anatomy, embryology and paleontology — points strongly to the conclusion that *Hutchinsoniella* represents a life form with a history of almost no change over a period of hundreds of millions of years. Moreover, when this modern cephalocarid is compared to various hypothetical crustacean ancestors that have been postulated by different students, it is remarkably similar to their imagined reconstructions.

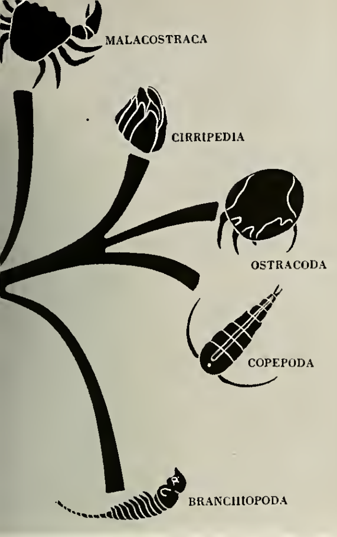
Accepting the ample evidence that *Hutchinsoniella* is in all probability the most primitive known crustacean, what can the animal provide in the way of clues to the relationship of the crustaceans to other members of the phylum Arthropoda?



Family tree of the crustaceans shows *Hutchinsoniella* as most primitive of living examples. Relation of extinct

The most primitive class of arthropods was, undoubtedly, the Paleozoic trilobites, extinct for at least 200 million years. In the trilobites, the appendages on both the head and trunk were, except for the first pair of limbs, identical. These appendages were biramous, that is, the leg gave rise to an inner branch (endopodite) and an outer one (exopodite). The endopodite had seven joints, and the segment making up the base of the leg had spinous lobes, called gnathobases, on its inner margin, which were used in feeding. Each of these limbs was used both for feeding and locomotion, and no appendage was specialized for any specific function. Certain of the same limb components can be demonstrated for the spiders, horseshoe crabs and the eurypterids, and it is now quite widely accepted that all these groups were derived from this initial trilobite stock.

Now, there exists a provocative and remarkable assemblage of fossils from the mid-Cambrian Burgess Shale deposits of British Columbia, 450 million years old. The arthropod fossils of these deposits are strikingly diverse in appearance. Some are typical trilobites; others could be included in the group that gave rise to the modern Xiphosura, represented by the horseshoe crab; while still other individuals are mark-



trilobites and crustacea is not clear: latter may derive from former, or both may descend from common ancestor.

edly crustacean in appearance. All the varied forms have one important feature in common; they possess the characteristic trilobite limb and the trilobite appendage pattern. Primarily for this reason, even the Burgess Shale "pseudocrustaceans" have been placed within the Class Trilobita.

Crustacean antecedents, however, are still poorly understood. Until fairly recently, it was generally believed that the trilobites were also the ancestors of the Crustacea. At present, the prevailing concept—largely as a result of the detailed studies of the Norwegian paleontologist, Størmer—is that the crustaceans and trilobites are *not* related.

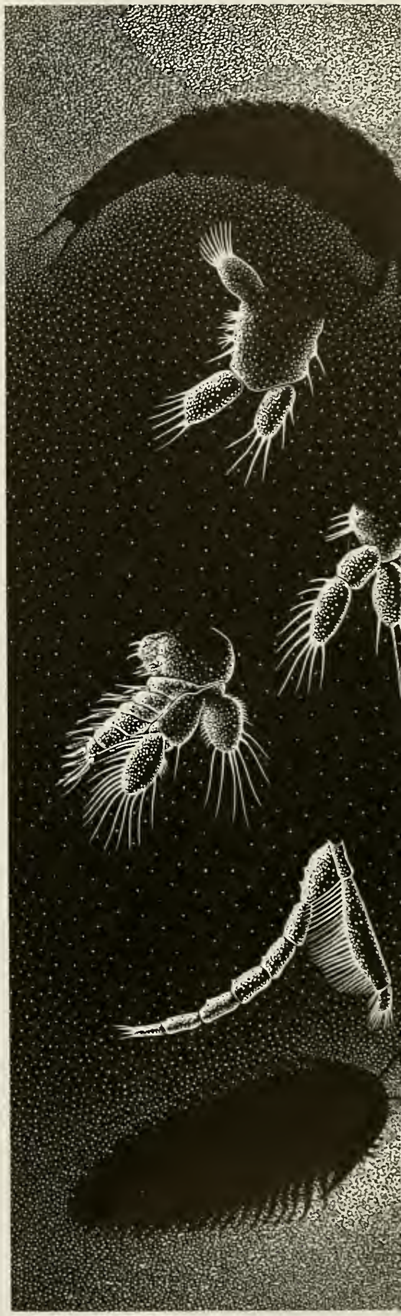
In fact, some even believe that both groups were evolved independently from different non-arthropod ancestors. They argue that neither the generalized limb series found in the trilobites nor the trilobite appendage can be detected in any known member of the Crustacea, even in the Paleozoic forms—although the gnathobases we see in trilobites do occur on the trunk limbs of the branchiopods. Instead, they point out, crustacean limbs are characteristically specialized for different specific purposes in different regions of the body. Those on the head have either a feeding or a sensory function, while the limbs of the trunk region are utilized exclusively for swimming or crawling.

The new-found *Hutchinsoniella*, however, possesses some remarkable non-crustacean, trilobite characteristics. All appendages, except the first, are used both for obtaining food and for locomotion and, contrary to all other Crustacea, no *Hutchinsoniella* limb is specialized for a specific function. This is precisely the pattern that was present in the trilobites.

Furthermore, the limbs of *Hutchinsoniella* are structurally similar: that is, no appendage is very markedly modified from a basic common plan. In fact, the last head limb (second maxilla) is identical to the trunk limb series. No such clear-cut homology of parts can be demonstrated among the appendages in any other crustacean, nor is there a case where a head limb bears a structural resemblance to the trunk appendages. Finally, *Hutchinsoniella*, alone among the Crustacea, retains what seems to have been universally present in all trilobites, a seven-jointed endopodite.

All this, I feel, shows clearly that the trilobites and the crustaceans *must* have been related, although it is difficult to determine whether the crustaceans evolved from the trilobites or whether both groups were derived from a common ancestor. It is just possible that the Burgess Shale "pseudocrustaceans" may represent a precrustacean stage of evolution which could have served as precursor to the crustacean stock.

In any case, it seems clear that the primitive arthropod limb pattern consisted of a series of identical appendages, with each limb serving at least a dual function. With the evolution of the Crustacea, there was a specialization of these appendages, with the loss, on the head limbs, of the component used for locomotion and the concurrent loss of the feeding parts of the trunk appendages. Our new addition to the ranks of the animal kingdom, *Hutchinsoniella*, seems to represent an arrested, early stage in this ancient line of evolution, since its limb pattern is intermediate between the original arthropod plan and the scheme found in all other crustaceans. Of course, the phylogeny of the Crustacea still leaves many and vast questions to be resolved; but it would seem to be one of history's characteristic ironies that so tiny a creature as *Hutchinsoniella* has helped us properly to pose them.



Fossil limbs — *Lepidocaris* on top, trilobite below — recall two different cephalocarid limbs *(center)*: trilobite, in endopodite joints; *Lepidocaris*, in leaflike limb without the endopodite.

PART II

THE NEW STONE AGE

Early Europe's hunters and collectors used new tools and methods to adapt to the postglacial environment as husbandmen and farmers

By Jacques Bordaz

THE GLACIERS RECEDED from most of Europe about ten thousand years ago and the vegetation belts moved northward. Tundras and steppes, with their large herds of reindeer and horses, were replaced by vast coniferous and deciduous forests where elk, deer, aurochs and boar predominated. These early postglacial times are called by prehistorians the Mesolithic period.

The Mesolithic was for prehistoric man a period of drastic adjustment to the new environment. In dense forests, game is neither so plentiful nor so easily found and killed as on open plains. The remains of mesolithic culture reflect this austerity: they are much less spectacular than those left by upper paleolithic hunters, for mesolithic man left us neither cave paintings nor carving in bone or antler. The greater time he needed merely to obtain the basic necessities of survival left mesolithic man less leisure. Nonetheless, excavations of mesolithic living sites have shown that these postglacial inhabitants were most resourceful in adapting to the new environment.

To augment hunting, the men of the Mesolithic increased their use of other sources of food. Some societies left huge accumulations of shellfish debris. Archeologists' recovery of fish spears (single or multipronged), fishhooks, traps and nets (with weights and floats) indicates that mesolithic man was systematically collecting other sources of protein than the wild game of the forests.

There were also important changes in hunting methods. Tracking and bringing down game in the forests was made easier by man's use of the first animal to be domesticated—the dog. The bow and arrow, more accurate than spear-thrower and spear, became the principal weapon.

The most characteristic flint implements of the Mesolithic are the microliths, the very small flints that first made their appearance in Magdalenian levels of the Upper Paleolithic. Varying in size from a half-inch to two inches, they were designed to form the points or cutting edges of a number of wooden or bone implements. Arrows, for example, usually were tipped or barbed with these small flints. Some archeological evidence indicates that microliths were, on occasion, fixed to the sides of arrow shafts with a resin, which would melt in a wound. The microliths, thus loosened, caused more bleeding and further weakened the quarry. A similar device is used by Australian aborigines at the present time.

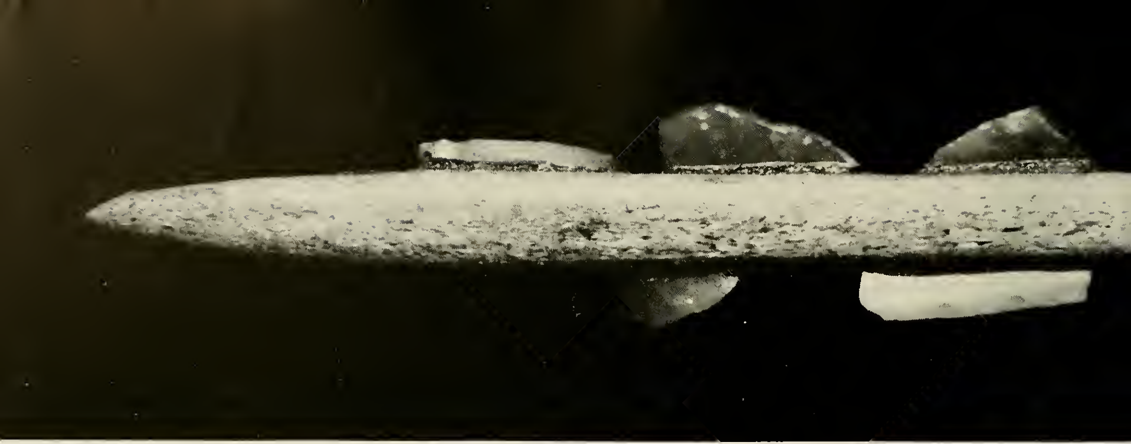
Microliths were manufactured from very small blade nuclei (see Natural History, January, 1959), sometimes no more than an inch high, or by fragmenting larger blades by means of a notching technique. Once flaked or fragmented, the tiny flints were frequently retouched, especially in later mesolithic times, until they assumed standardized forms such as crescents, triangles and trapezes (see following page).

Microliths were used by all societies of the Mesolithic period. For some who lived on sandy soils near the sea or in rocky highlands, they were the principal implement. But other groups, established in forested areas of northern Europe, had started to develop types of heavy stone tools for felling and shaping timber. These were the first heavy stone tools to be made since the flaking of bifaces was abandoned at the end of the Middle Paleolithic.

This ancient technological tradition in all probability had been lost: in any case, it was with entirely new types of tools that the men of the Mesolithic period worked wood to make staves for skin-covered boats, paddles, sledges, bows and arrows, other wooden artifacts and the framework of their huts. Among these new tools, the most remarkable were the heavy stone adzes and axes—usually made by inserting flint heads into antler sleeves, which were themselves perforated for the insertion of wooden shafts. For the first time, certain stone implements had edges shaped by grinding, rather than flaking, and some were perforated so that handles could be inserted directly into the stone blade.

The importance of this new stone technology was to increase greatly with the introduction into Europe of food-producing techniques. In the Mesolithic, the felling and shaping of timber had been largely limited to the wood required to make hunting and fishing equipment: and the European forest cover remained almost unchanged until about 6,000 years ago. At that time, groups of immigrants brought to Europe the revolutionary food-producing techniques that had originated in the Middle East: the cultivation of wheat and barley and the breeding of cattle and swine, as well as such new accomplishments as weaving and pottery-making. Europe's hunting and fishing peoples

Miniature size of some mesolithic implements is shown by comparison with the point of a neolithic dagger, *center*. The inch-long core, *left*, furnished the tiny blades: larger blade fragments, *right*, were retouched in geometric shapes.



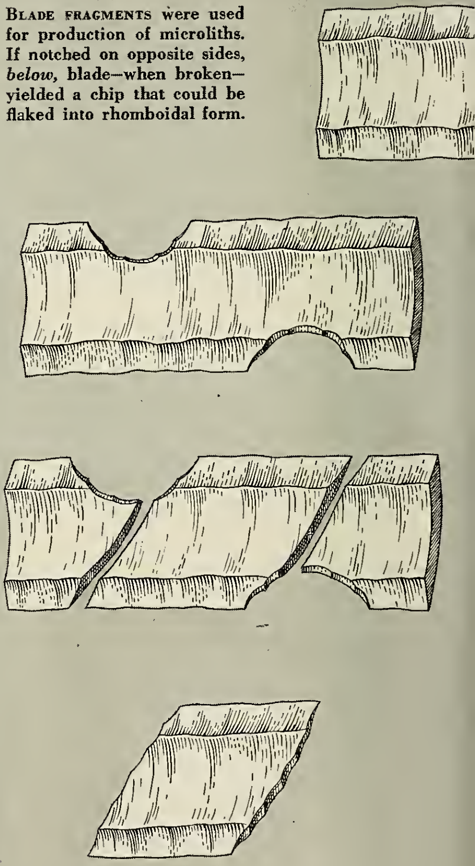
usually had not settled in the most densely forested areas, but, for these immigrant farmers, dense vegetation was an indication of soil fertility; so, it was in precisely such areas that they first settled.

Archeological evidence points to a primitive type of cultivation involving constant clearing of patches of forests by felling and burning. Then, after a few harvests, the superficial layer of the soil became exhausted and the farmers moved on to new ground. The communities of these early cultivators grew rapidly. A typical community probably numbered between two hundred and six hundred members. When its population increased beyond this maximum, a group would branch off and clear a new area of its own. Never staying in the same location more than a few years—during which they enjoyed the initial richness of the newly cleared soil—these groups diffused rapidly over most of Europe, deforesting much of the land.

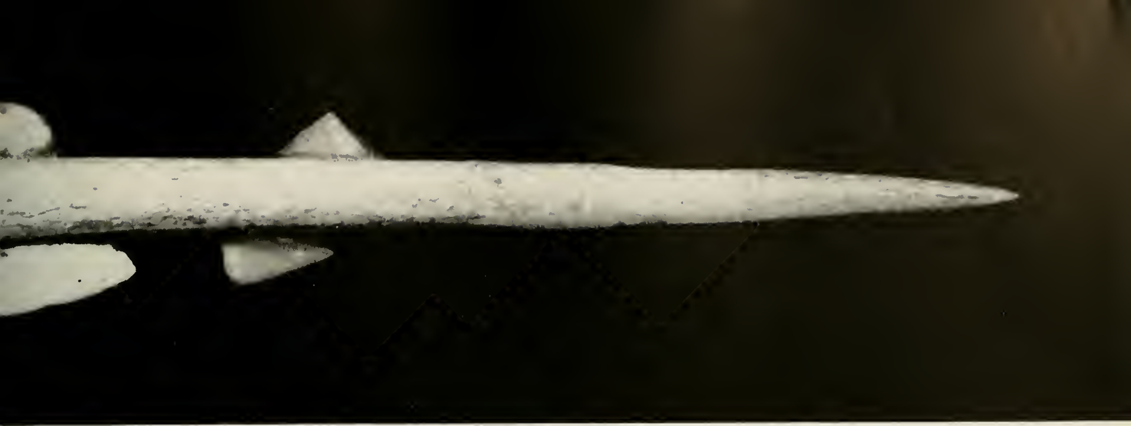
The shifting type of cultivation practiced by these early settlers did not prevent them from building substantial wooden houses—which were sometimes reinhabited when the soil had lain fallow long enough to regain fertility. Examples of such early neolithic houses, excavated at Köln–Lindenthal, in Germany, were built of timber and measured thirty to a hundred feet long by fifteen to twenty feet in width. These structures, with mud-plastered walls, probably were used as both granaries and living quarters.

Excavations of one middle neolithic village—on the shores of the Federsee in South Württemberg, Germany, uncovered twenty-two rectangular houses, twenty to thirty feet long by about fifteen feet wide. The main features of their floor plans are strikingly like the houses occupied by American farmers on marginal land in the South today. A wide porch, probably covered by an extension of the gabled thatch roof, gave onto an anteroom. This anteroom contained a hearth and a clay oven, and was separated by a partition from a second room. The walls, of split timber, were plastered with mud and the plank floor was covered with a layer of earth.

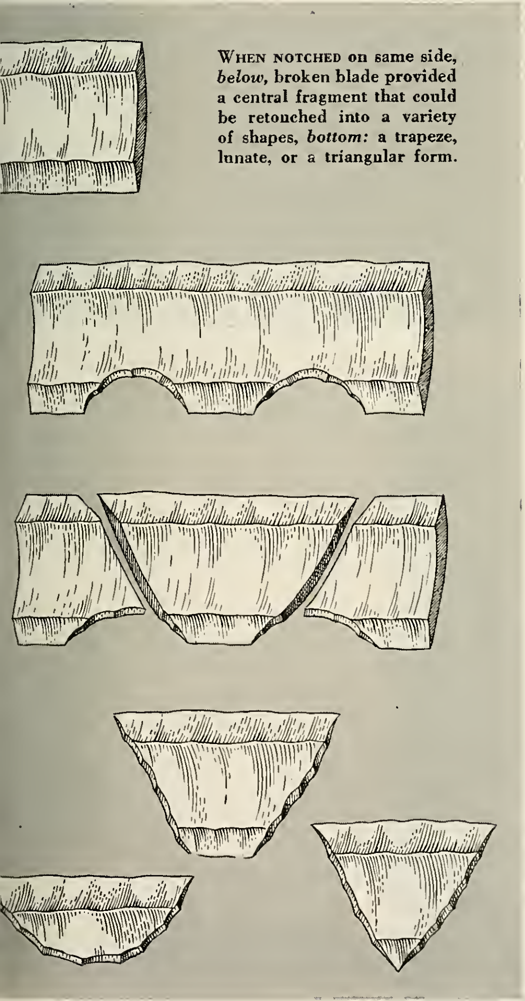
Both the great importance of forest clearance in this new economy and the extensive use of timber in building made the adze and axe—and such other carpentry tools as chisels and gouges—a most important part of the equipment of these farmers. It will be recalled that some



Blade fragments were used for production of microliths. If notched on opposite sides, *below,* blade—when broken—yielded a chip that could be flaked into rhomboidal form.



Microliths were used in a variety of ways, by setting the sharp flints in wood or bone. This bone point is six inches in length: its "barbs" are fixed with resin cement.



When notched on same side, *below*, broken blade provided a central fragment that could be retouched into a variety of shapes, *bottom:* a trapeze, lunate, or a triangular form.

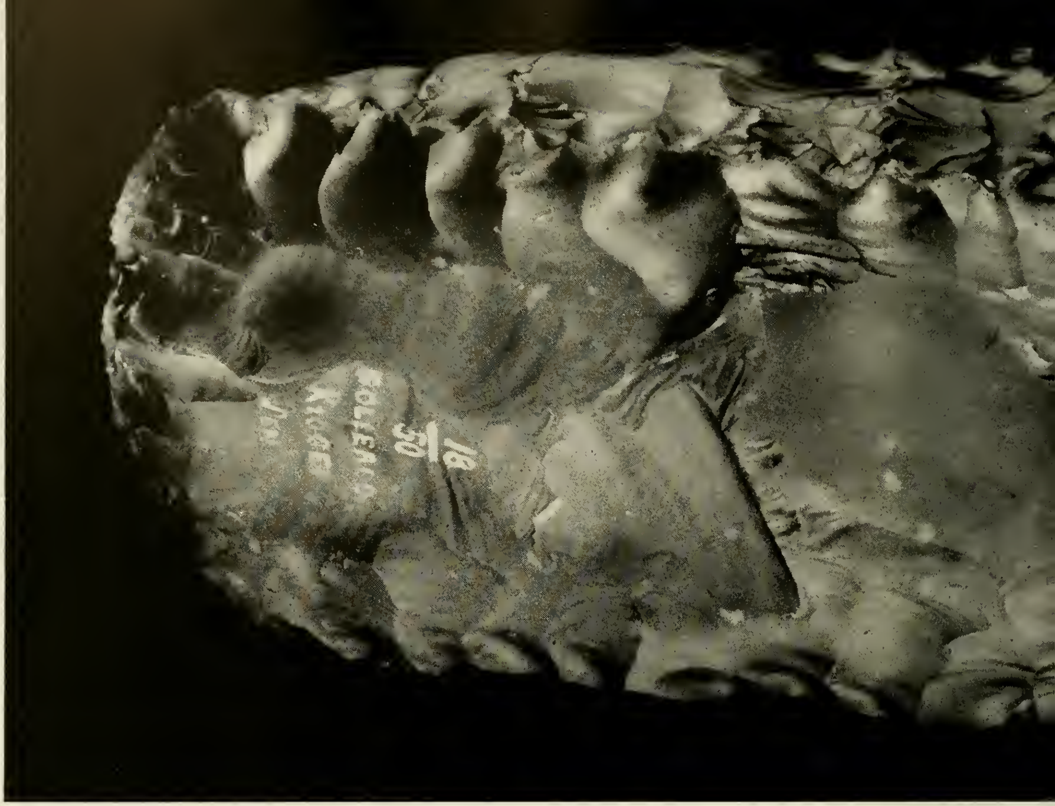
mesolithic "celts" (the term by which prehistorians generally refer to axe and adze blades), although shaped by flaking, had their working edges ground by abrasion. This technique of shaping stone tools became predominant among the agriculturalists. They usually employed grinding to shape the entire implement. It was for this that prehistorians called the new era the age of New [i.e., grinding method] Stone, or Neolithic, in contrast to the age of Old [i.e., flaking method] Stone, or Paleolithic.

The advantage of a polished celt (polishing refers particularly to the last and finest grinding) has been demonstrated experimentally. Wood can be chopped faster with this type of tool: the smooth head penetrates deeper than a flaked axe, and the strong, symmetrical edge withstands the force of the blow much better than a flaked edge, which, because of unequal distribution of stresses, is more likely to break or chip. Indeed, polished axes are remarkably durable and efficient. Modern experimenters felled a fir tree more than two feet in diameter in eighteen minutes with such an axe, while oaks more than a foot in diameter were cut down in half an hour, without any damage to the polished stone blade.

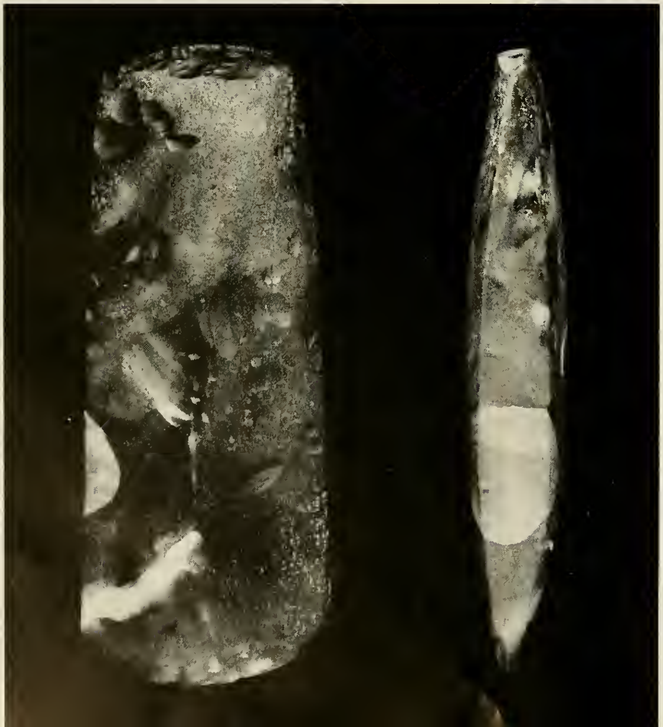
To manufacture a polished stone celt, a nodule was first flaked into a shape approximating that of the desired implement. This "rough blank" was then ground by rubbing on slabs or outcroppings of gritty rock, such as sandstone. The finish, or final polish, was usually obtained by rubbing the implement with a finer-grained stone, using sand as an abrasive. Wetting the sand gave a smoother finish. Portable grinders, presumably used to resharpen the celt's edges when necessary, have been found.

The over-all efficiency of an axe or adze depends in large measure on the way it is mounted on a handle. Most neolithic axe handles were cut from the roots or branches of oak or ash. Generally, the stone tool was then mounted in one of two fashions: either the celt was perforated, permitting the introduction of a handle, or the handle was perforated or morticed, so that the celt could be set into the wooden handle.

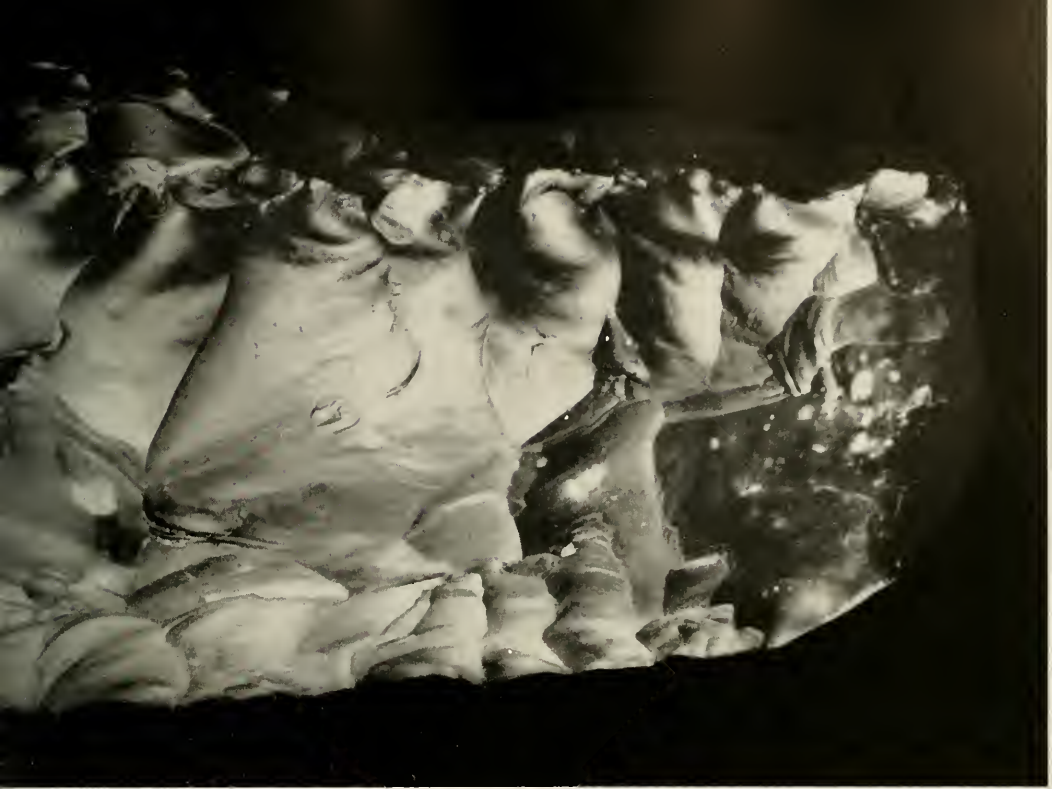
The first would seem to be the better method: perforated tool heads are usual with the axes and hammers of



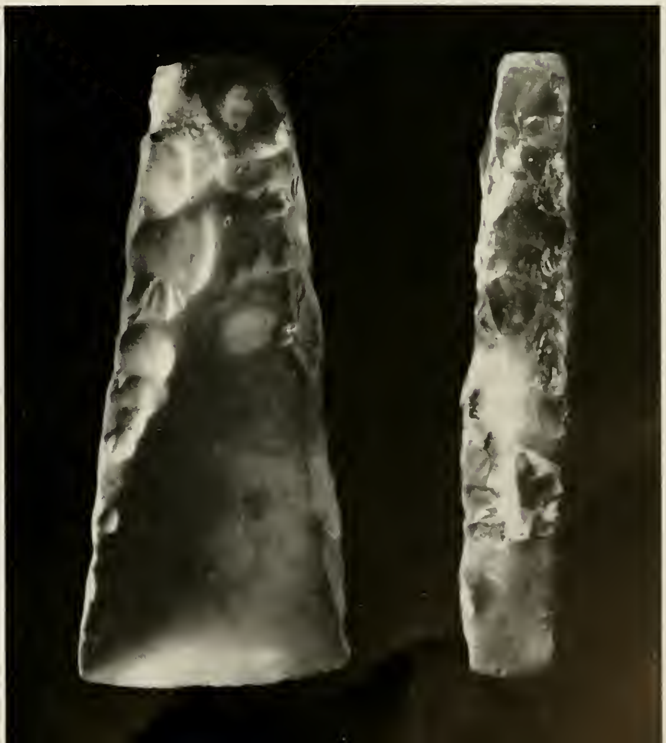
Flint "blanks" like the Danish one, *above,* were common trade items during the Neolithic. They were roughed into shape by percussion at quarries



Axe head, from a Danish neolithic site, is seen in front and side view. Six inches long, tool was brought to final form by grinding and polishing.



where superior flint was available and traded in this unfinished form. Then they were worked into finished adze or axe blades by process of grinding.

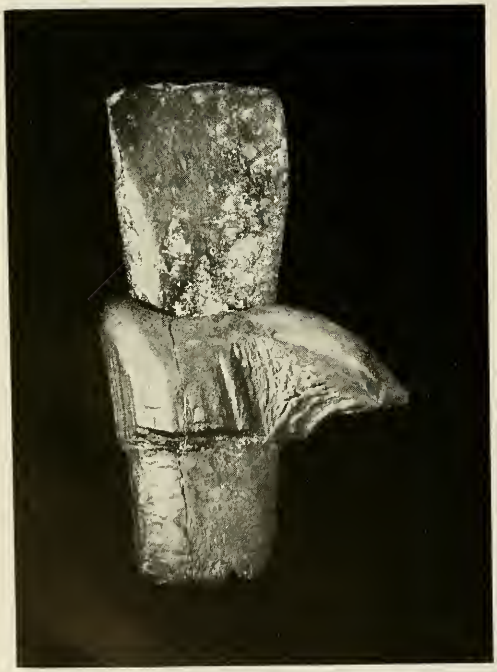


CARPENTRY TOOLS, *right*, from the Danish Neolithic, are — in order — a hollow-ground gouge and a chisel. The grinding is limited to working edges.

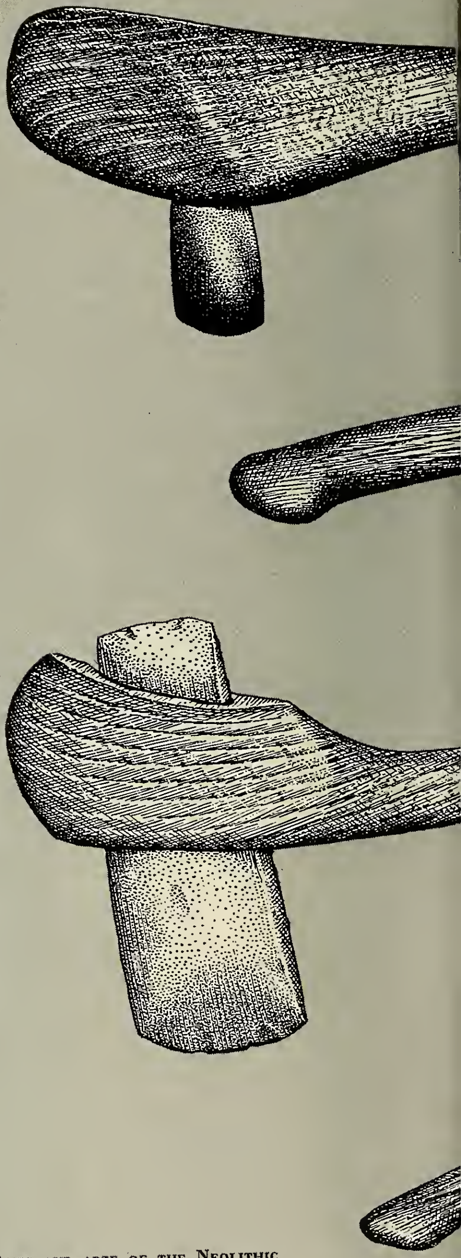
MR. BORDAZ, of Columbia University, herein concludes his history of stone technology in Europe. As with Part I, the artifacts—photographed by LEE BOLTIN in monochromatic light—are all from THE AMERICAN MUSEUM'S collection.

today, while some mace heads were mounted in this fashion as long ago as the Mesolithic in northern Europe. However, this method of mounting was rarely used during the Neolithic. One probable reason lies in the effort required to drill through stone without the help of metal tools. Indeed, consider the steps involved in the earliest method: first, sink a lead-hole in the tool's side by means of percussion with a hammerstone. Then, with a round wooden stick and sand, bore the hole deeper. Because most of the abrasion is done by the sides of the revolving stick, and very little by the tip, it is necessary, after a time, to use percussion on the tool again, pounding a new lead in the bottom of the cavity—then, back to drilling. However, after a certain depth is reached, it becomes impossible to use the hammerstone to sink a new lead in the bottom of the cavity without widening the entire hole excessively. The implement is therefore turned over and the same procedure repeated until the two holes meet at the center. Even so, the shape of the resulting, biconical perforation resembles an hourglass.

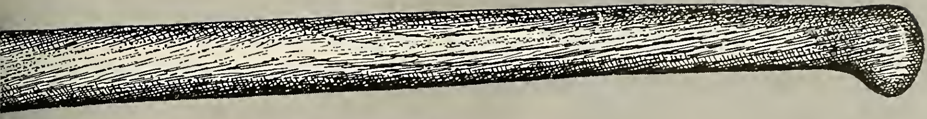
A great improvement over this laborious method was the hollow-boring method. A strong, hollow reed is rotated as a drill, with sand for an abrasive. This cuts a cylindrical core, which falls out when the opposite side of the



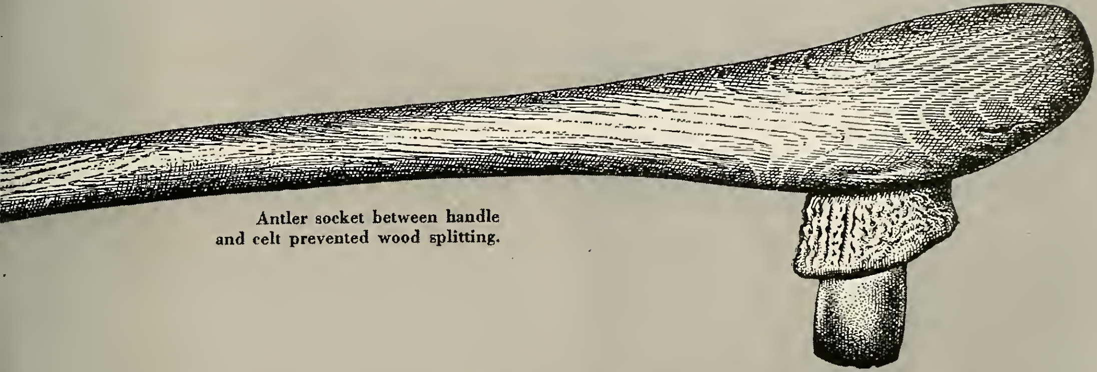
ANTLER SOCKET, *above*, with its base cut to fit a wooden handle, served as shock absorber for this neolithic celt.



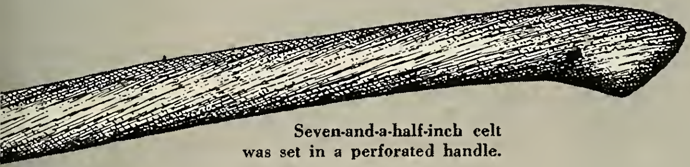
AXES AND ADZE OF THE NEOLITHIC show the development of improved hafting techniques. Direct method, *top*, caused handle to split, but antler "shock-absorber" helped to overcome this. Adze, hafted at an angle, *bottom*, was for fine work.



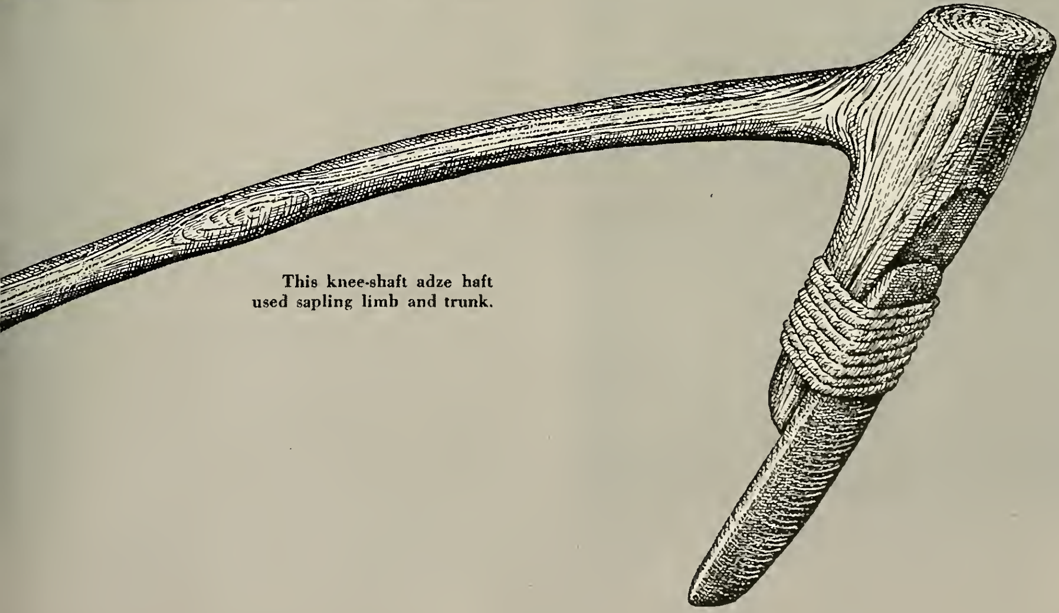
Three-and-a-half-inch celt
was set directly in wooden handle.



Antler socket between handle
and celt prevented wood splitting.



Seven-and-a-half-inch celt
was set in a perforated handle.



This knee-shaft adze haft
used sapling limb and trunk.

tool is reached. Thus, a perfect perforation is obtained, with far less work involved than in the earlier, biconical technique. Use of bow drills presumably further reduced the investment in time.

Despite such improved techniques, few perforated stone implements have been recovered from the Neolithic. For, quite aside from the work involved, the shaft hole through the stone weakened the implement excessively. The shock of each blow, combined with the strain caused by wedging of the handle, tended to break the celt in a short time. Hence, the neolithic preference for the second method of hafting—perforating or morticing the handle itself. One means of doing this was to place the celt directly into a perforation or a mortice in the handle.

The disadvantage of this method was that the shocks of use drove the celt into the softer, wooden handle, and eventually split it. But, another means of mounting was used by the neolithic craftsmen to prevent the handle from splitting. It consisted of using an antler socket as an intermediate piece. This socket acted as a shock absorber, while a stop ridge, ground around the socket (or sometimes a thick spur) prevented the celt from being driven through the handle by use.

Another particularly efficient means of mounting—especially for adzes—was knee-shaft hafting. For this type of hafting, a short section of a sturdy sapling, with a projecting branch was selected. The trunk portion was then split, to accommodate the celt, while the branch served as a handle. In other cases, the celt was lashed to the side of the trunk portion. While the latter would not seem to be as strong as a split mounting, it has the advantage of allowing the adze blade to strike almost parallel to the surface of the wood being worked.

Knee-shaft hafting was very popular, and not only in neolithic times: in later periods, knee-shaft hafting was used for metal tools in most of northern Europe. Its main advantages lay in simplicity of manufacture, good balance and the fact that the blade did not tend to split the handle (as did the blade set in a perforated handle).

Danish battle-axe, seven inches long, is a meticulous copy, in ground stone, of an original made out of copper.

Increasing demands for stone of good quality for heavy, woodworking tools during this period must have depleted a great number of Europe's most accessible sources of flint. Neolithic man began to mine extensively for this material. Shafts as deep as fifty feet—sometimes connected by radial galleries about six feet high—have been found at Spiennes in Belgium. At Grimes Graves, in Norfolk, the mined area covers more than thirty-four acres. Flint of superior flaking quality was mined there, as well as at locations in northern and northwestern Europe and we have reason to believe that the mining was done by local specialists, who preflaked the nodules into rough shapes and traded them in this "blank" form.

The shortage in supplies of flint of good quality, and of other flakable stone, was largely solved by the development of still a third technique of stone-shaping—one which made possible the manufacture of tools from many sorts of common stone. The new development employed a crumbling, battering or pecking method. Mesolithic man had already used this technique to a limited extent, but it is only in the Neolithic that the shaping of stone implements by crumbling found wide use. In combination with grinding, this technique permitted a great number of dense, fine-grained stones to be used for implements—material that could not have been satisfactorily shaped by flaking.

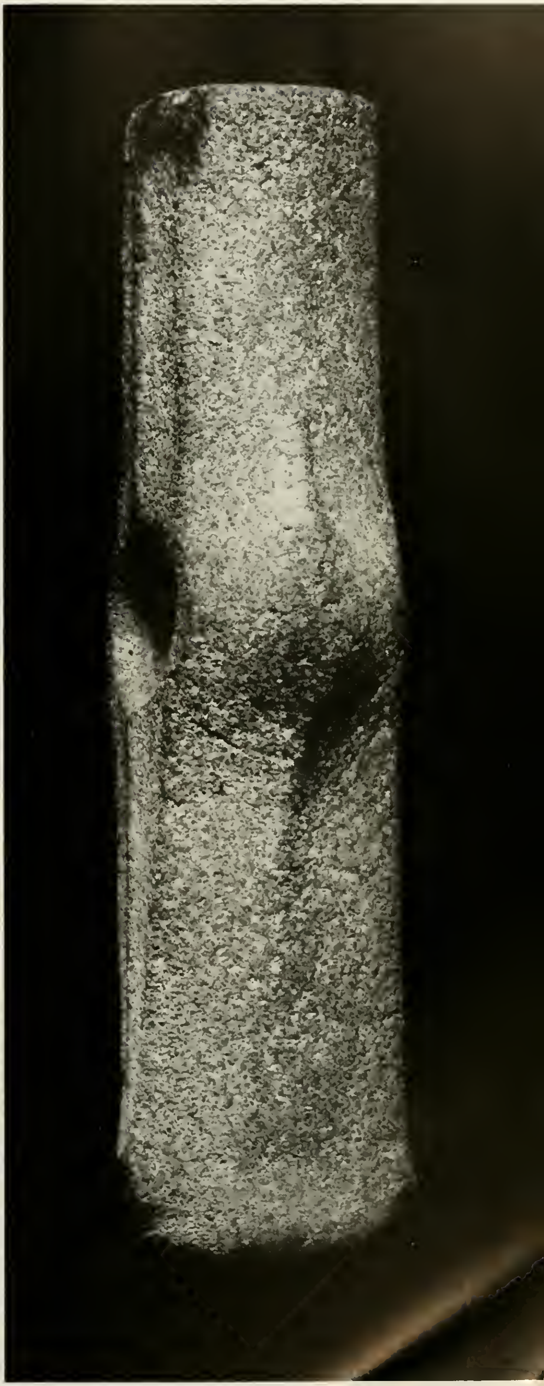
This new process consisted of "hammer-dressing" the potential tool's surface; by crumbling it away with repeated light blows of different-sized hammerstones until the "blank" attained the required shape. Hammerstones of flint were especially useful for this repeated pecking. Not only was flint's superior hardness an asset, but the repeated blows against the tool detached minute flakes from the flint hammerstone, leaving hundreds of very sharp edges, which acted like so many tiny chisels on the surface of the stone being shaped. Once pecked to rough shape, the implement was finished by grinding. Still another way to shape implements of non-flakable stone was by sawing—using retouched flint blades or sand as the cutting agent, and wood or bone as the "saw."

These new methods—pecking and grinding tools out of common stone—were, of course, much more time-consuming than the flaking techniques. Contemporary studies of Australian aborigines have allowed us to break down the time required to manufacture a stone axe. For example, a diorite axe about eight inches long, four inches wide and two inches in thickness can—with luck—be roughed out by flaking in a few minutes. Pecking the surface of the axe, to remove the flake scars, takes an additional day or two, and grinding and polishing the axe to final finish, with sand and water on a slab of sandstone, consumes a further two days. The length of time varies, of course, with the fineness of the stone's grain and the size of the implement desired. It is noteworthy that contemporary Australian quarries—like the prehistoric European ones—are littered with unfinished implements, rejected because of a break due to an ill-placed blow, or a flaw in the stone.

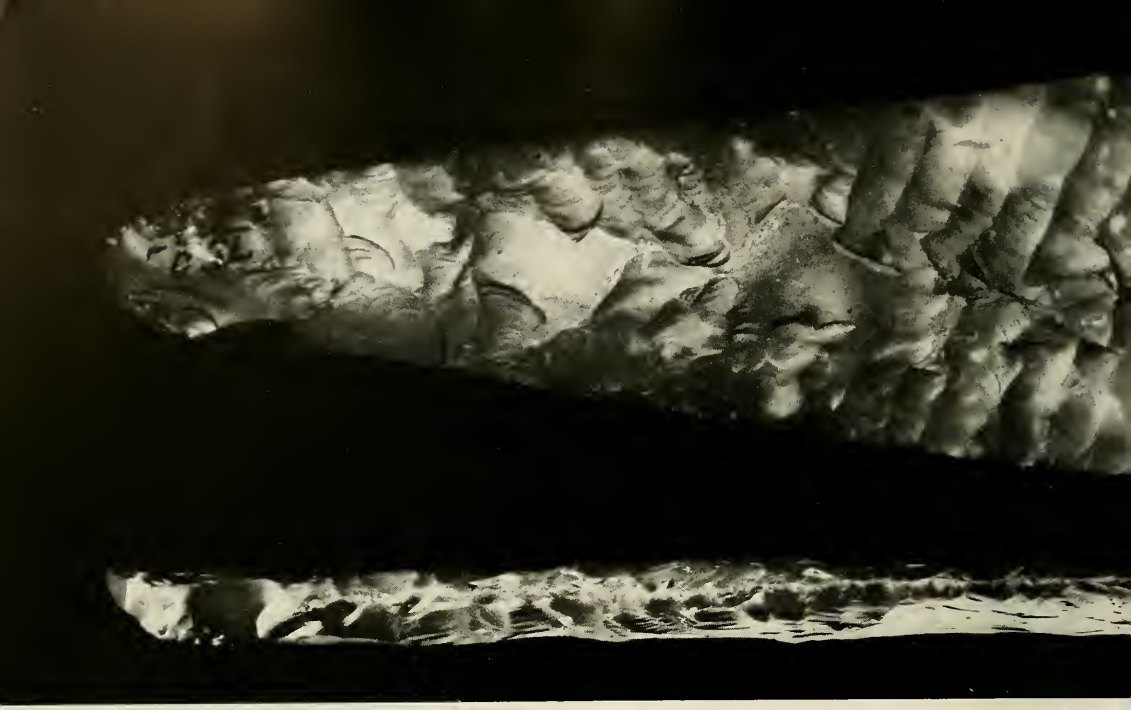
THE stone equipment of Europe's neolithic farmers consisted mainly of axes, adzes, gouges and chisels, reaping implements, querns and hoe blades. The excavation of these neolithic settlements indicates a peaceful life. But in later times—possibly because the fast-growing population competed for the better agricultural and pasture lands—one finds these villages protected by moats and palisades, while stone weapons appear in large numbers.

One look at the stone axes illustrated, *left and right*, on pages 100-101 will suffice to indicate that their conception is totally different from that of the stone implements previously manufactured. For these are careful copies in stone of metal originals—the, as yet, extremely rare and precious copper axes that were so admired and envied by the late neolithic farmers of northern Europe. The splayed edge of one specimen is reminiscent of the splaying of a repeatedly hammered copper blade; the longitudinal ridge simulates the seam of a metal piece that has been cast in a closed mold. And, in both, the shaft holes are features more suited to metal than to stone, for we have seen that celts are excessively weakened by such holes.

The metal originals that inspired these battle-axes—and the flint daggers shown here—were first introduced into Europe about 4,000 years ago by itinerant Aegean smiths, who had learned metallurgical techniques originating in the Near East. Early copper and bronze implements were no sharper than flint implements, but they had a number of other important advantages. First, metal is not so brittle as stone: where a celt may break or chip, copper or bronze merely bends. Axes, adzes and saws of metal are more efficient than stone for cutting wood, because they



ANOTHER STONE COPY of a metal original, this neolithic weapon from Denmark shows the casting seams of prototype.

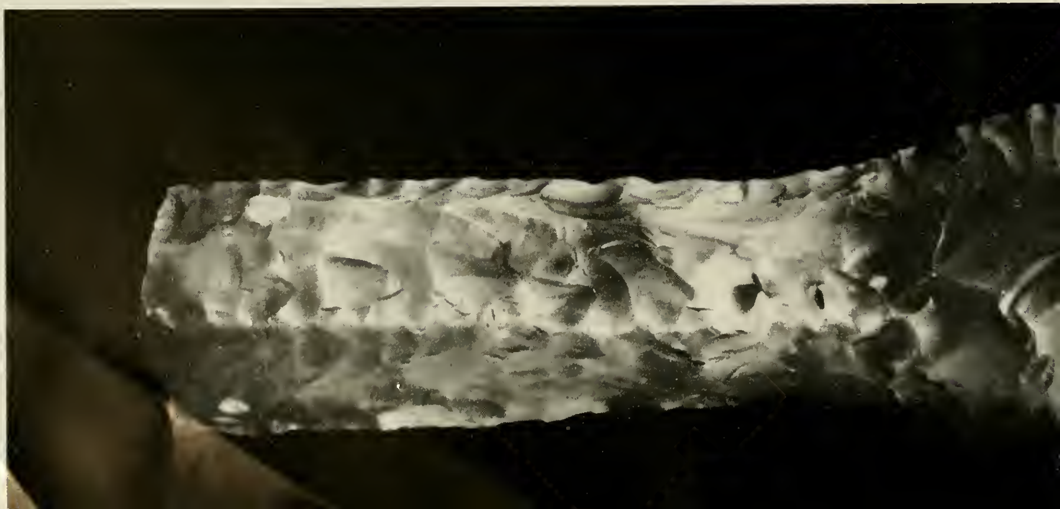


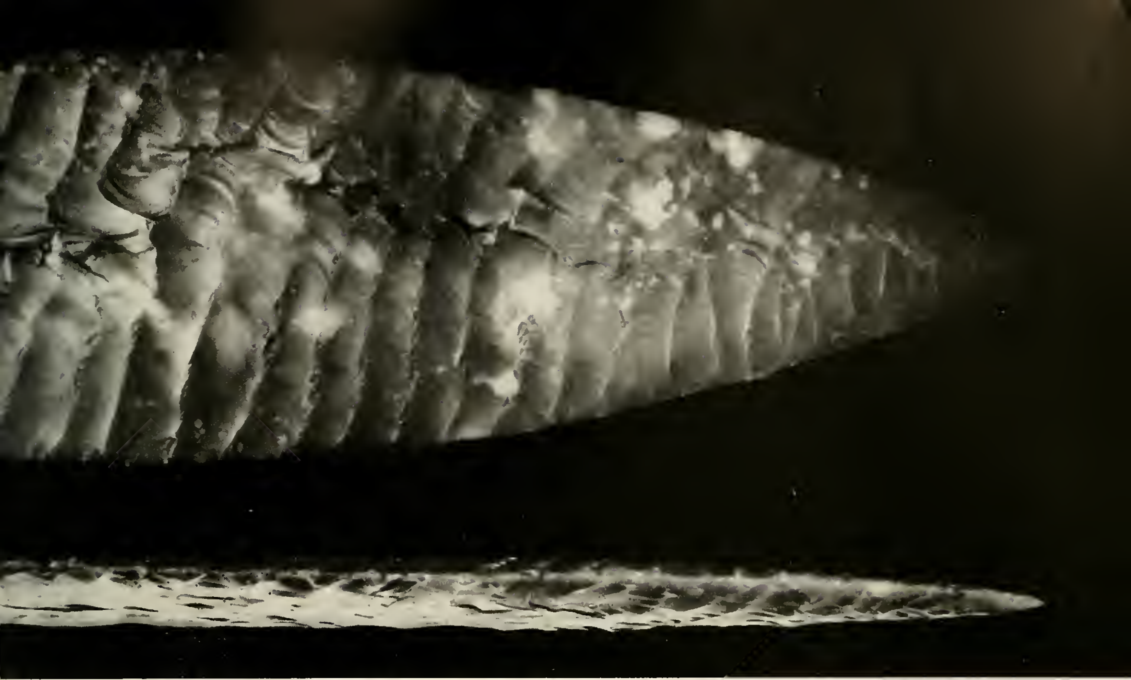
Ultimate skill in the art of pressure-flaking is displayed, *above* and *below*, by two Danish late neolithic copies of metal daggers. The weapon at top is over ten inches long

can be made thinner and thus cut deeper. Moreover, by casting, metal can be formed in a wide variety of shapes and worn-out tools may be remelted and cast anew.

In spite of all these advantages, stone was only slowly replaced by metal. At first, use of copper and bronze was restricted to ornaments and weapons. Only later were these metals used for craft tools, such as axe, adze and saw, and the use of metal for domestic and agricultural implements came much later and infrequently. Indeed, it was not until the last centuries before Christ—with the introduction of iron, a more abundant metal—that the tradition of stone implements was abandoned in Europe.

In other parts of the world, stone continued to be used. In the New World, for instance, implements—some as magnificent as the Danish daggers of the Old World—were knapped. Indeed, these New World stone tools and weapons brought about De Jussieu's suggestion, in 1723, that the ceraunias were actually the implements of prehistoric Europeans. At about the same time, the flintlock firearm was invented, and for about a century—until the invention

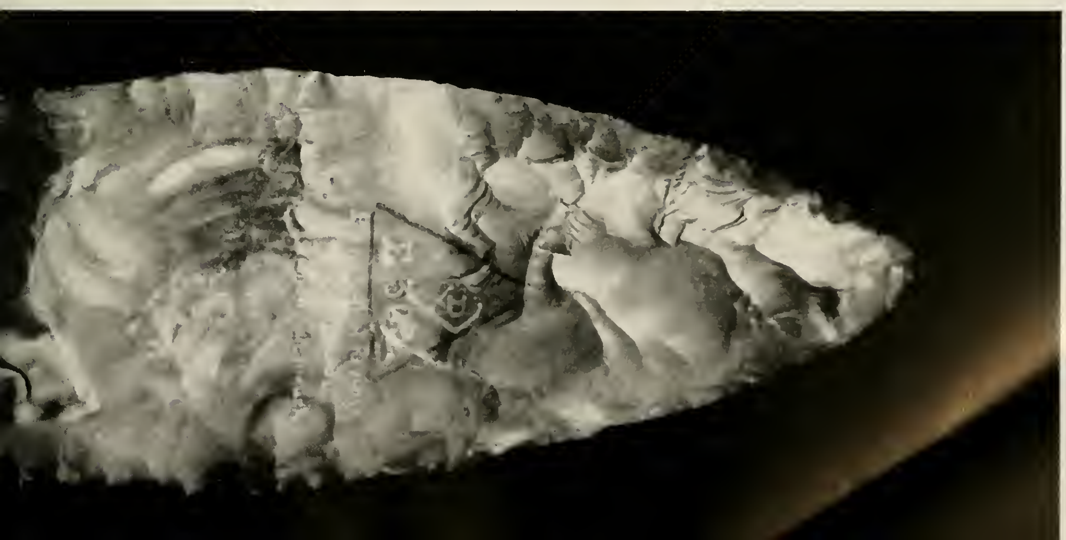




but only a quarter of an inch thick. Lower one is eight inches long. The first step was to grind the flint blank to symmetrical shape, after which the surface was flaked.

of the percussion cap—this new use for flint brought about a renaissance of the art of knapping. At Meusne in France and at Brandon in England, places where especially good flint was available, millions of gunflints were produced during this period. Indeed, the Brandon knappers are still exporting gunflints to West Africa.

Today, the half-million-year-old art of knapping flint—and similar silicious rocks—is, in the main, known only to the scholars concerned with prehistory—and to a few hard-working counterfeiters, here and abroad, who find it profitable to make replicas of mankind's earliest implements for the curio trade. Pecking and polishing techniques, in turn, are still used by sculptors, masons and lapidarists. In a few areas of the world, all these ancient techniques—percussion-flaking and pressure-flaking, and pecking and grinding—are still used by a handful of primitive peoples. These people are the last to use stone for tools and weapons—the last heirs to a technological tradition that made it possible for man not only to survive for millennia, but, also, to establish the base for all mankind's further cultural development.



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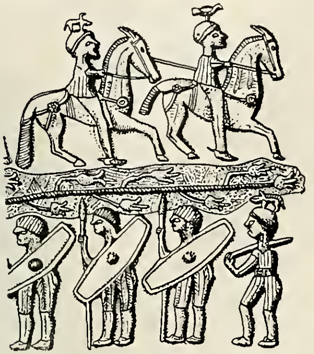
REVIEWS

(continued from page 64)



DESIGN ON BOWL is taken from *The Celts.*

graphic regions, by Robert A. Norris) are followed by an exhaustive catalogue of the birds of Georgia, with discussion of breeding, range and distribution. It should be noted that the book stays very strictly within the scope indicated by its title, with the result that there is relatively little behavioral information (this may be found in more general handbooks) and that the breeding habits of species that do not nest in Georgia are not discussed. The illustrations, done with taste and accuracy, are a model for future illustrators to follow.

BIRD WONDERS OF AUSTRALIA, by A. H. Chisholm. *Michigan State University Press, $5.00; 243 pp., illus.*

THIS BOOK, as its title indicates, is not a comprehensive guide but a selective treatment—the selection being done with a taste for the unusual, and the treatment with the emphasis on behavior. Thus, one finds chapters on the bower birds, which paint their nests; those master singers, the lyre birds; and the honey-eater with its predilection for human hair. The author is a writer as well as an ornithologist, and the book reads easily. A pleasant excursion into an interesting region.

THE CELTS, by T. G. E. Powell. *283 pp.* THE ETRUSCANS, by Raymond Bloch. *260 pp. Praeger, $5.00 each.*

HERE are two new books in the "Ancient People and Places" series, of which a previous volume has already been discussed (NATURAL HISTORY, October, 1957). The series, conceived under the general direction of Glyn Daniel, with each volume written by a distinguished specialist, aroused high expectations and, as the contributions grow in number, these hopes are fully justified.

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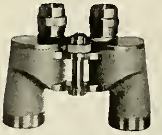

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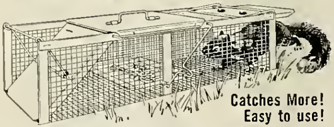

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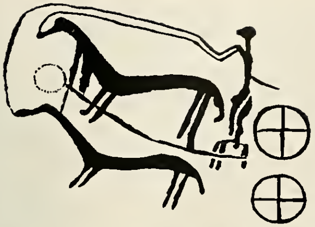

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virtually the entire western part of that continent and much of its central part as well: it was they whom the Romans of Caesar's time and later fought against in what is now France, Spain and Germany. Their civilization formed the soil in which Roman culture took root, and innumerable aspects of modern Europe, even to the shape of the fields and the boundaries of land holdings, bear the Celts' mark. The present book discusses their way of life in as much detail as is known; but probably of greater interest to most readers will be the Celts' extraordinarily rich mythology—their attitude to the supernatural, their rites and the tradition of oral lore, kept and passed on by the druids. These things hold our imagination today as strongly as ever; and the present book offers the most convenient summary available of what we know about them.

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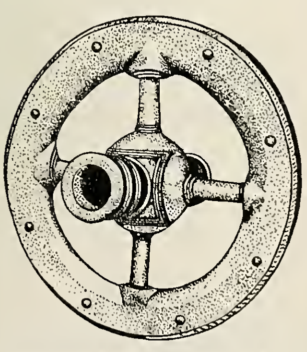

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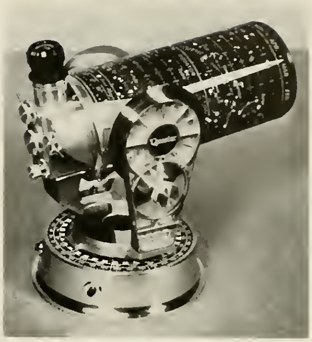

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as much about the Etruscans as any man; his book is the finest treatment of the subject in English.

Among the other recent volumes in this generally fine series that deserve particular mention are those on *Denmark before the Vikings*, by Ole Klindt-Jensen—a very important, thoroughly engrossing and, by the broad public, undeservedly neglected region; and *Wessex*, by the late J. F. S. Stone, which is centered about a masterly presentation of the now-restored site of Stonehenge.

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Mexican Bird Songs will be much appreciated by the increasing number of tourists and amateur bird watchers who visit or reside below the border. The more serious bird student, aware of the extent of geographical variation in bird song, may hope that future recordings of similar nature will be identified as to locality, on the record or the jacket.

Reviewed by:
WESLEY E. LANYON.
THE AMERICAN MUSEUM

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84-5—star map by Henry M. Neely.
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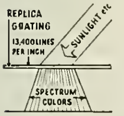

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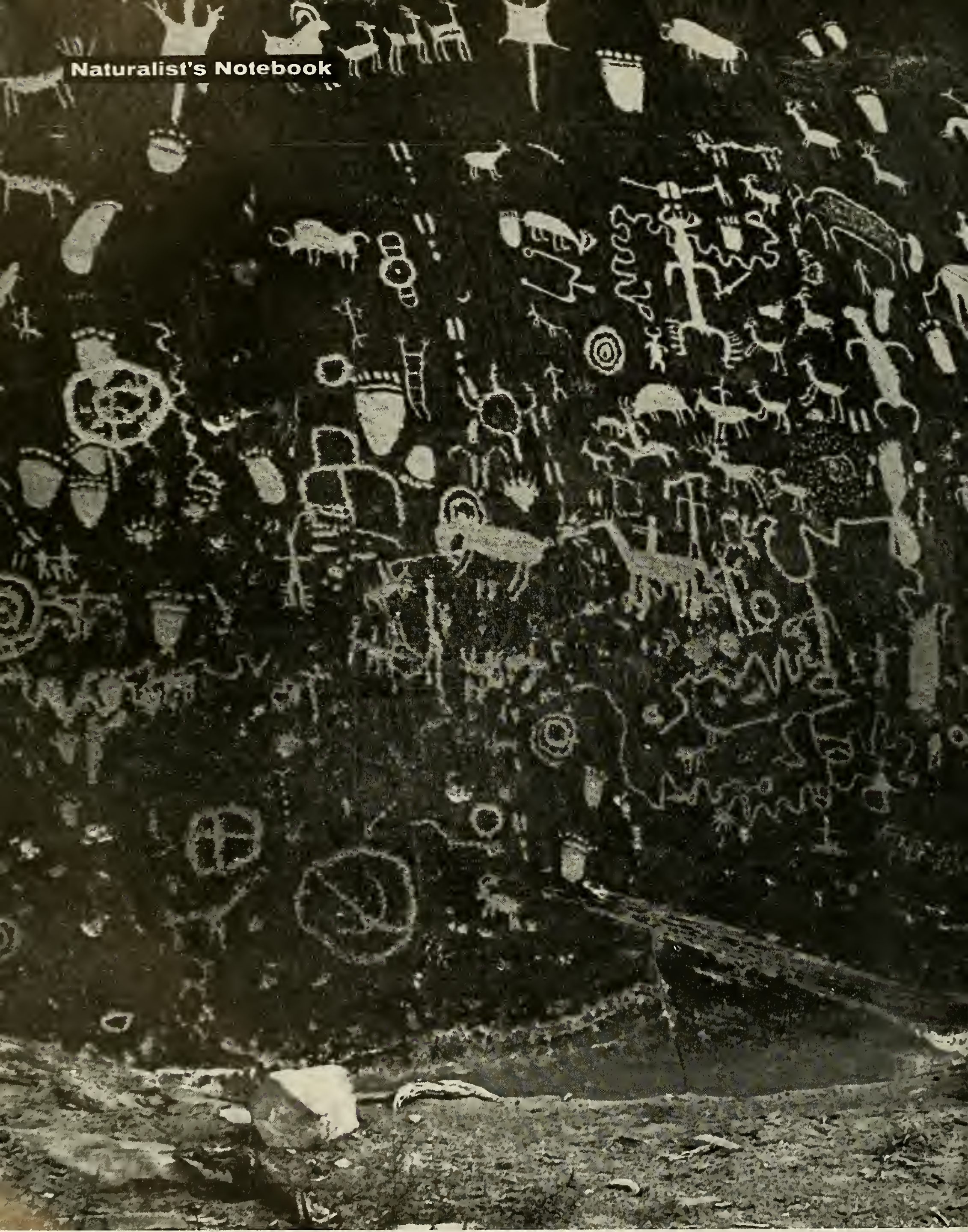
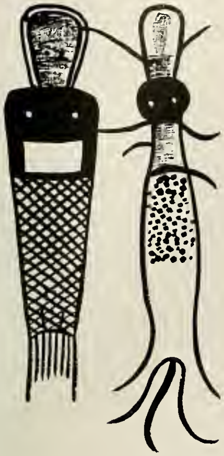


ARRAY OF PETROGLYPHS, covering fifty square yards of cliff face at Indian Creek, near Moab, Utah, is believed to be the largest such assemblage in the western United States. Half the total are nearly obliterated by weather.



PETROGLYPHS IN PERIL

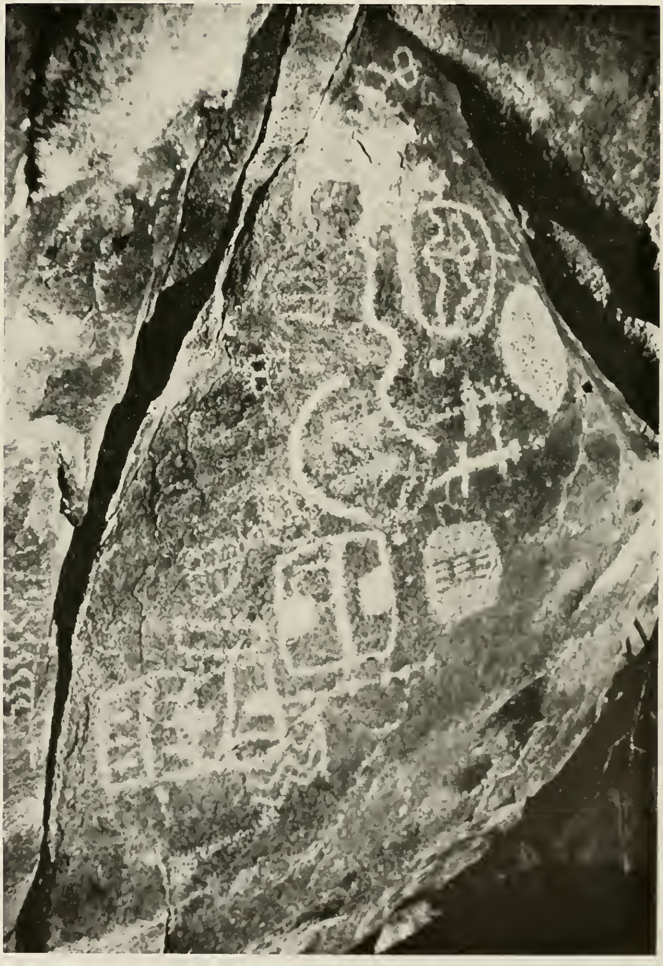
A western artist is busy preserving them

By Ethlyn Gorsline

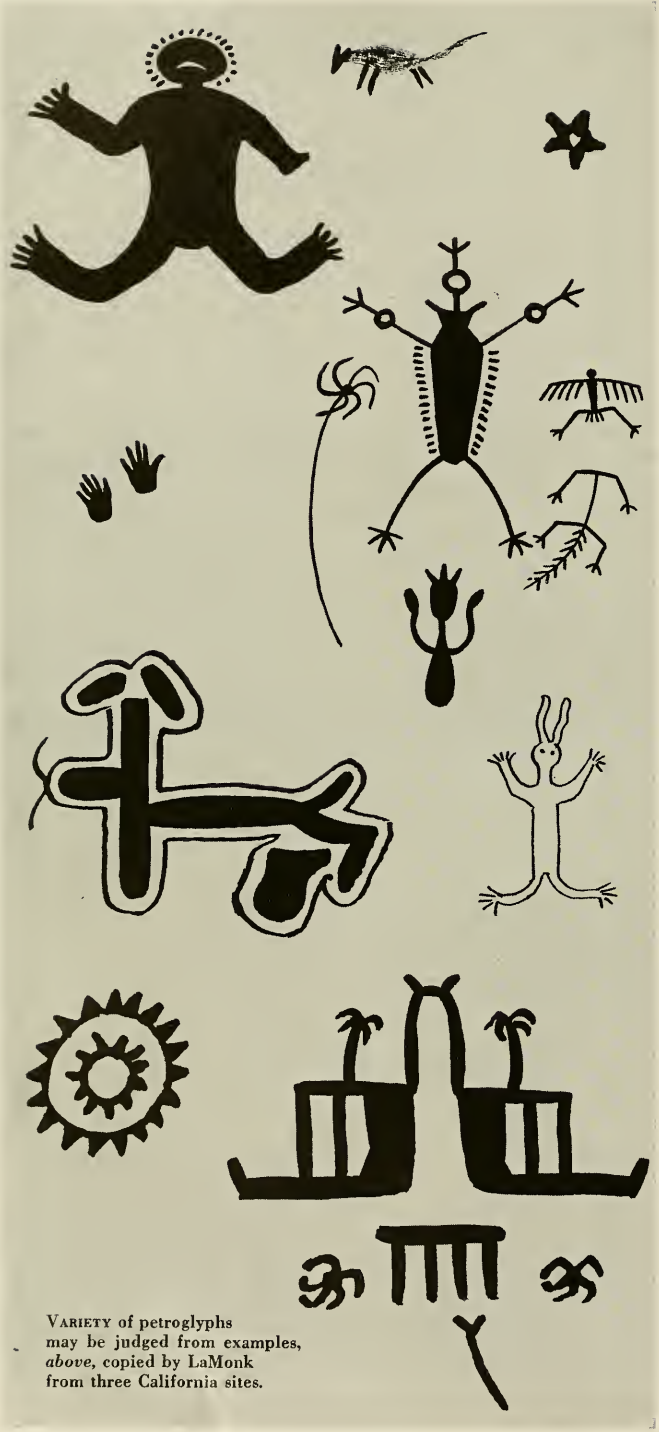
IN VERY NEARLY every part of the world, from the central Sahara to the luxuriant islands of Polynesia—and abundantly throughout the western United States—examples of a universal occupation of mankind are to be found. Known collectively (and imprecisely) as petroglyphs, these carvings and paintings—on boulders, exposed rock faces or the walls of caves—are at once appealing to the archeologist's imagination and irritating to his sense of scientific propriety. For they can seldom be dated—there are few clues to the identity of their creators—and their subjects, in the main, are more a matter for guesswork than for scholarly analysis.

The extent of some petroglyph displays in the United States may be judged by the photograph, *left*, of a rock face in eastern Utah. Yet, many such monuments to man's past have vanished in recent years, victims of the elements or acts of vandalism. The great Painted Rock, in California, is an example. Once a continual mural that spanned sixty feet—vivid with reds and yellows—this monumental work has been completely obliterated by thoughtless souvenir hunters.

ONE MAN who is working today in an effort to preserve at least some of these fast-fading legacies is Charles LaMonk, of Palmdale, California. In the past twelve years, LaMonk has traveled widely in that state, making meticulous copies of cave paintings and rock-cut figures. In the course of this work, he has developed a number



SEARCHERS may discover petroglyphs in many parts of the western U.S. The inscribed boulder, *above*, was found at Keyhole Canyon, in southwest Nevada.



Variety of petroglyphs may be judged from examples, *above*, copied by LaMonk from three California sites.

Mrs. Gorsline, a New Englander by birth, has resided in California for many years. In her travels as a free-lance writer, she met Mr. LaMonk and prepared this account of his efforts.

of special techniques that allow him to record not only the color but even the texture of the original work.

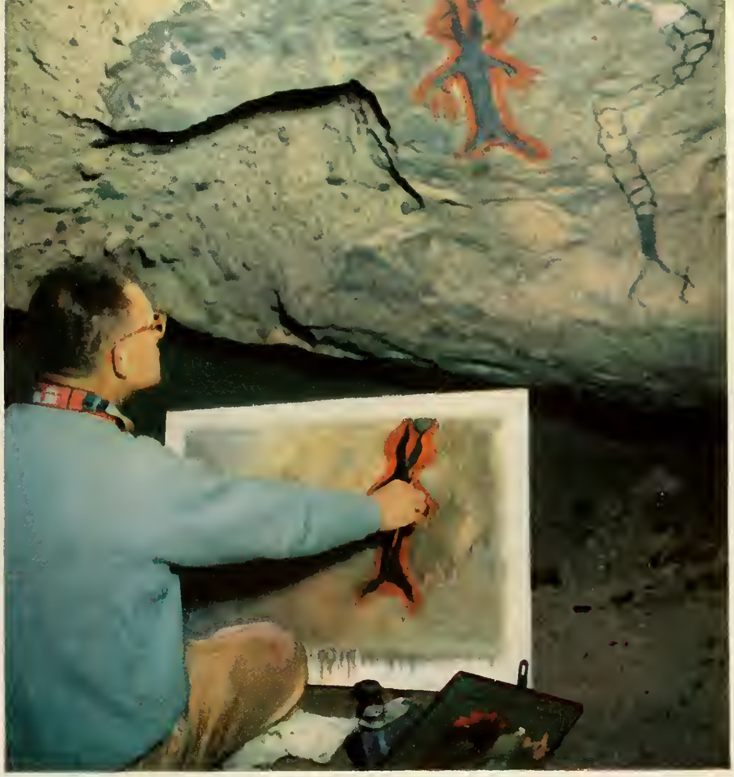
A good eye and a trained hand may suffice for preservation of the simple outlines and stick figures that constitute the majority of petroglyphs (examples, at *left*). But to capture the effects, say, of smoke-stained ocher and white, applied with a brush of frayed deerskin to a rough stone surface, requires additional craft.

Starting with a masonite panel. LaMonk spreads it with a heavy coat of white lead. While this coating is still wet, he covers it with a layer of rock dust and sand gathered from around the site of the painting to be copied. When the panel dries. it is an almost identical replica of the original rock. The artist is then ready to paint on a background that has both the texture and shading of the original.

When his subject is a true petroglyph—that is. an intaglio. pecked into the stone surface—LaMonk creates a similar effect by building up layer on layer of sand-strewn pigment until the contours of the original rock surface have been duplicated.

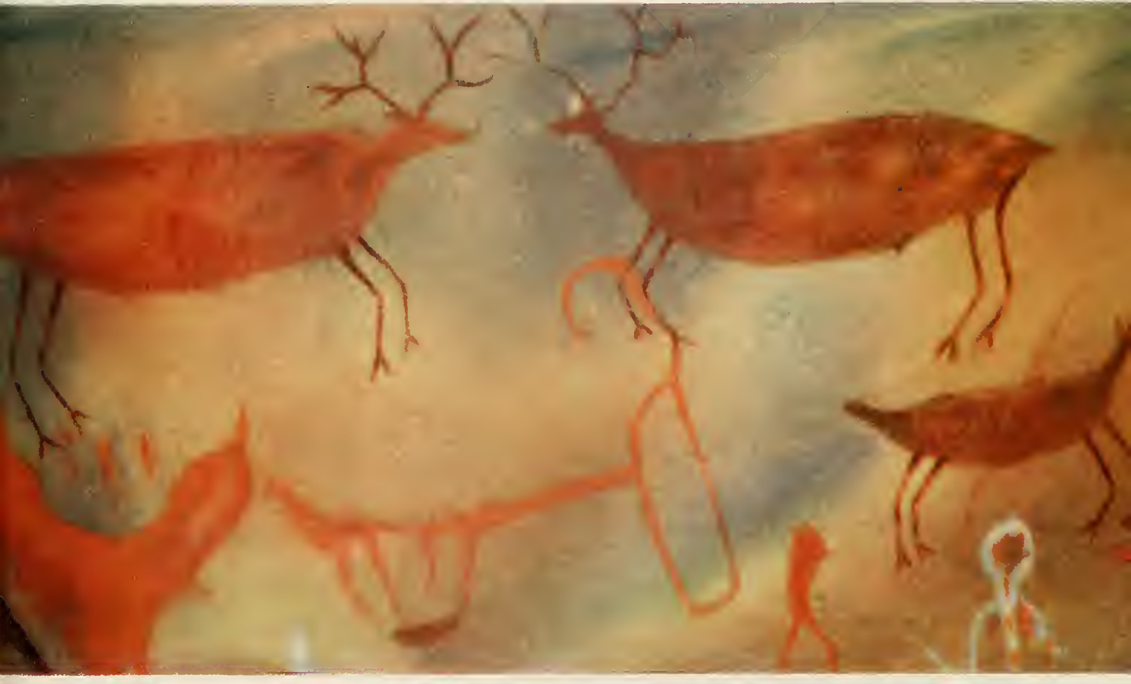
LaMonk's mission has taken him to many out-of-the-way locales. He has found his originals high on rock ledges and in caves so small that, lying on his back, he has copied paintings on a ceiling less than a foot above his face. In one such locale. his position for copying proved identical with that of the original artist—at exactly the right angle and distance from his hand were the rock depressions that his predecessor had used to hold pigments. and one of these ancient paint cups still showed traces of color.

On the opposite page, LaMonk is shown in the process of copying a rock painting found in a cave in the Tehachapi Mountains of California. The panel, *below*, is his copy of an original from the Pinto site, in Inyo County. that now hangs in the Southwest Museum, Los Angeles. LaMonk continues this painstaking work today. determined that as much as possible of this aboriginal inheritance be preserved for modern Americans.



Cave painting is copied by artist LaMonk with meticulous care on a panel that has been previously prepared to simulate a stone surface. He calls this a "teddy bear."

Horned ungulates, copied from rock painting at the Pinto site, seem to have been cut from the original matrix. This and other of LaMonk's work were exhibited at the Brussels Fair.



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THE CORAL POLYPS seen feeding in the cover photograph—which was made available to NATURAL HISTORY by Dr. Thomas Goreau of the University College of the West Indies—are one among the thirty-six species of reef-building corals that inhabit the tropical waters of the Western Atlantic today. Although these polyps are being nourished with minced clam in an aquarium, the corals normally feed on living prey—for they are active, although anchored, members of one of the most unique biotic assemblages in nature.

The reef-building corals, and their vast, oceanic monuments—especially those in the Pacific—have caused wonder, as well as scientific argument, for generations. For a review of the contesting theories of Darwin and Daly—and new light on the coral questions—turn to page 118.

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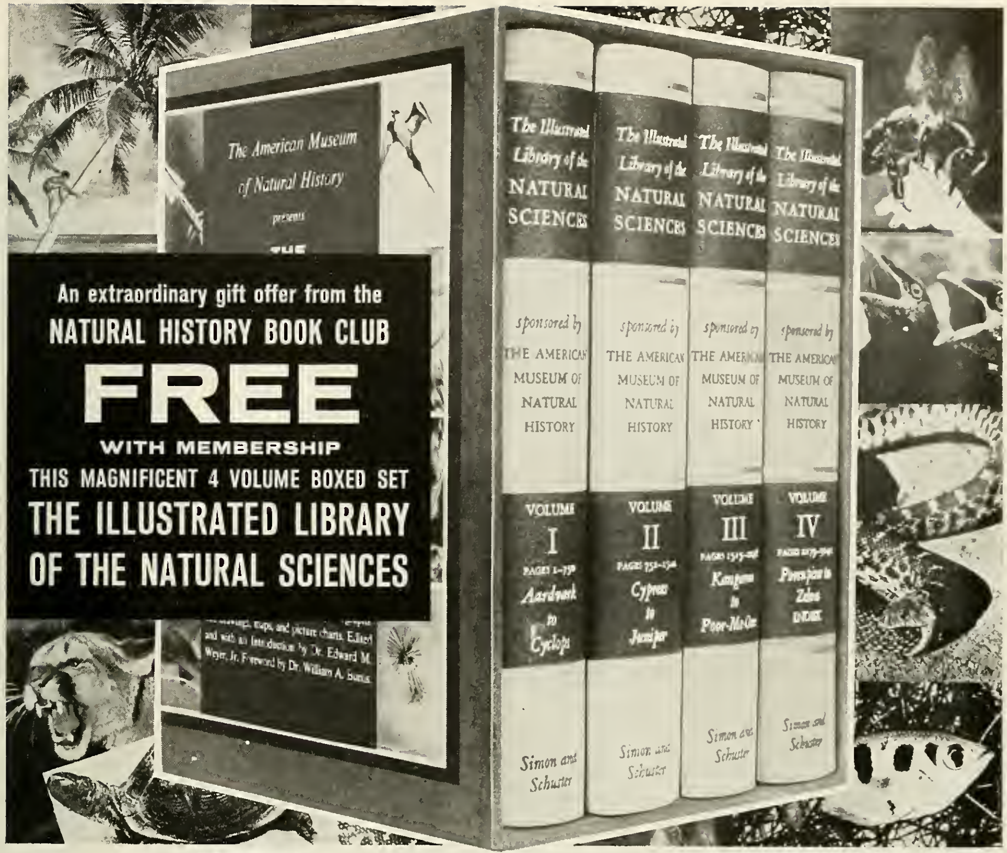
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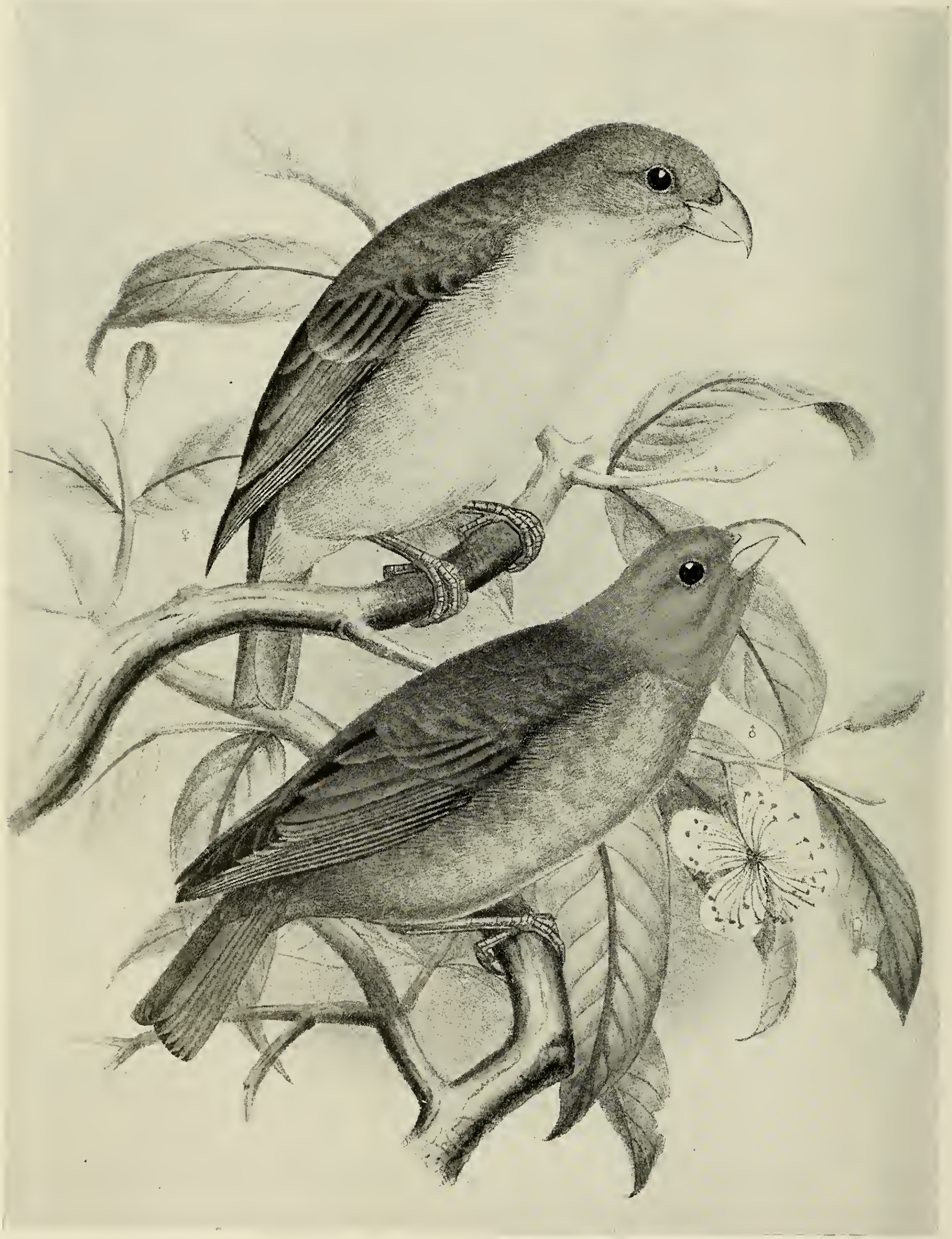


The Ou, *Psittacirostra psittacea*, is one of the Drepaniidae—a family which has evolved wholly within the Hawaiian Islands.

Reviews

THE ECOLOGY OF ANIMALS AND MAN

Reviewed by MARSTON BATES

THE ECOLOGY OF INVASIONS BY ANIMALS AND PLANTS, by Charles S. Elton. *John Wiley, $5.25; 181 pp., 50 plates, 51 figs.*

THE WORD "ECOLOGY" was coined by Ernst Haeckel in 1870, to cover the study of the "outer phenomena" of animals, leaving physiology—in a narrow sense—to mean the functioning of their insides. The division is as logical as any that can be made among the sciences: some people are more interested in taking animals apart to see how they work; others, in the behavior of the whole animal in its relations to other organisms and to the environment. The two approaches require different kinds of apparatus, somewhat different sorts of skills in observation and experimentation. To be sure, they are interdependent. It is impossible to understand the behavior of an animal without knowing what is going on inside it; and impossible to understand the insides of an animal without knowing something about the circumstances under which it lives. But the division into ecology and physiology—into skin-out and skin-in biology—is recommended by its convenience.

Ecology is based on the same Greek root as economics (*oikos*, meaning household) and, in effect, ecology is the study of the economics of nature. Ecology is also, clearly, a rather new word for an old subject, natural history. The value of changing the name is debatable. Ecology sounds more "scientific," of course, but science does not depend on Greek roots, and the coining of erudite-sounding words can easily become a vicious habit—has become a habit with many people who call themselves ecologists. This leads to a situation that makes it possible to say, as Charles Elton once remarked, that "ecology consists in saying what everyone knows in language that nobody can understand"; or, to quote the famous quip of the late Karl Schmidt, that "ecology is that science in which a spade is called a geotome."

This need not be. Charles Elton has always called himself an ecologist, yet he has always written about the living world in prose that is beautifully clear and eminently understandable—a little book called *Animal Ecology* that Elton published in 1927 has become the classic of the subject. Elton's ideas have permeated all of contemporary ecology—but, unfortunately, his prose style has not diffused nearly as widely.

Ecologists have another characteristic. It seems to me that many of them are engaged in an elaborate and imaginative game of "Let's pretend that man doesn't exist." This is understandable enough. Man is always messing up the landscape and disrupting relations within biological communities; the ecologist wants to analyze the forces that molded the original landscape, that governed the evolution of community relations. He searches, consequently, for natural areas, for undisturbed conditions, for climax or stable communities. He has a hard time, because he is apt to live in Europe or the United States, where the influence of civilized man has been pervasive. But he has to play this game of "let's pretend" if he is to achieve any understanding of the forces that governed the living world through the vast span of geological time until man—only a few minutes ago, as geological time goes—explosively became a new and powerful agent of change.

The only trouble with this game is that it can lead the ecologist, consciously or subconsciously, to view man wholly as a nuisance—and thus to ignore the great possibilities for understanding that lie in the study of the very changes that man has produced. The accidental or purposeful modification of biotic communities through human action can be regarded as a series of gigantic experiments which, through this very disturbance, throw light on the nature of the community structure. It is this wider point of view toward man that Charles Elton has taken in *The Ecology of Invasions*. The result is a book that should be studied by every ecologist, for it enriches even basic concepts and is full of suggestions for further study. It is also a book that should be pondered by every conservationist, for it outlines ways in which we can achieve a more intelligent management of our biological resources. Finally, it is a book that can and should be read by everyone interested in the natural world, for it is written with Elton's usual clarity and simplicity and deals with topics of direct concern to all.

ELTON begins with a discussion of "The Invaders," built around seven case histories of organisms that have explosively invaded new regions when transported there by human agency. *Anopheles gambiae* (which was accidentally introduced into Brazil from Dakar and, in its new ecological situation, caused a fearful malaria epidemic until it was presently exterminated at

(Continued on page 163)

MAMMALS OF CENTRAL ASIA are seen in old engraving. Behind, wolves and three saiga antelope; front left, the mole-rat *Spalax*; right, a desman, a big water insectivore.

PART I

QUESTIONS OF

THE CORAL REEFS

A problem considered by Darwin more than a century ago is being resolved by studies in the West Indies and the Indo-Pacific area

By Norman D. Newell

After finishing a survey of the Galápagos Islands, on October 20, 1835, H.M.S. "Beagle" began a long voyage across the Pacific. Coming, after some weeks, to the "Low or Dangerous Archipelago," the expedition's young naturalist noted that he saw "several of those most curious rings of coral land, just rising above the water's edge, which have been called Lagoon Islands.

"A long and brilliantly-white beach," Charles Darwin recorded in his *Journal*, "is capped by a margin of green vegetation: and the strip, looking either way, rapidly narrows away in the distance, and sinks beneath the horizon. From the mast-head, a wide expanse of smooth water can be seen within the ring. These low hollow coral islands bear no proportion to the vast ocean out of which they abruptly rise; and it seems wonderful that such weak invaders are not overwhelmed by the all-powerful and never-tiring waves of that great sea, miscalled the Pacific."

The scene that young Darwin drew has been a favorite topic of romantic writing from the time of Melville to the present. But, while such works have made the South Pacific legendary, they have also served to obscure the fact that more accessible coral seas lie near at hand—among the island archipelagoes and rocky shores of the tropical western Atlantic from Rio de Janiero to Bermuda. Although the living reefs of the West Indies are small, post-Pleistocene newcomers when compared to many of the massive veterans of the Pacific, both deep borings and soundings of recent date indicate that some of the mightiest coral reefs ever known anywhere came into being in the Tertiary period, millions of years ago, along the southeast margin of the North American continent.

The main architects of coral reefs are tiny colonial animals of the coelenterate phylum, related to the sea anemones and jellyfish. They are assisted in their construction work by certain lime-secreting red algae, whose cemented, calcareous skeletons have accumulated on shallow sea floors the world round through thousands of years to make a firm but very porous limestone. In past geologic periods, other groups—including certain sponges, mollusks, Bryozoa and blue-green algae—produced great reefs, but these are not now important as reef architects.

This "almost-atoll" is the island of Maupiti, northwest of Tahiti. A protective coral reef around this sinking island accords with Darwin's theory of growth during subsidence.

Reef corals and algae require sunlight for growth. Consequently, they push upward toward the surface of the water, crowding together in profusion at low tide level. Stragglers from these colonies may extend more than two hundred feet underwater, sparsely inhabiting rock ledges and talus slopes beyond the edge of the reef.

There are many kinds of coral reefs, but the varieties that have long attracted scientific attention are the barrier reefs and atolls of the deep-ocean basins. Rising steeply to the surface above an ocean floor, thousands of feet deep, these reefs support rich, isolated communities of shallow-water organisms—mutually dependent plants and animals—living, as it were, in biological oases amid a desert of comparatively sterile, deep waters.

It seems strange that the growth of reef corals is stimulated by strong surf. Yet, the living outer edges of reefs successfully resist the pounding of all but the most violent of breakers, even growing forward at times toward the waves. Indeed, the death and erosion of reef corals are most rapid in sheltered places: a reef community thrives best in strongly agitated surface waters.

Because the growing surfaces of mature coral reefs are essentially at sea level, reefs are sensitive to slight changes in sea level and resulting shifts in the relative distribution of land and sea. Fossil reefs are therefore reliable datum points for ecologic interpretations of the sedimentary rocks in which they are found. In some places, ancient reefs—formed by algae, sponges, corals and other organisms, long buried under accumulations of sediments—contain large quantities of petroleum: it is becoming evident that a good proportion of the proved oil reserves of the world (nearly seven per cent of the total, if we except the non-reef oil fields of the Middle East) is contained in the porous rock of fossil reefs and associated lagoonal deposits.

Scientific theories are inherently tentative "progress statements" about knowledge: they must be overhauled and modified from time to time as new evidence becomes available. In the search for knowledge, conflicting and seemingly contradictory theories, supported by opposing camps of competent investigators, rarely prove to be wholly right or wrong. This is true of the main theories that have been advanced to explain the origin of coral reefs.

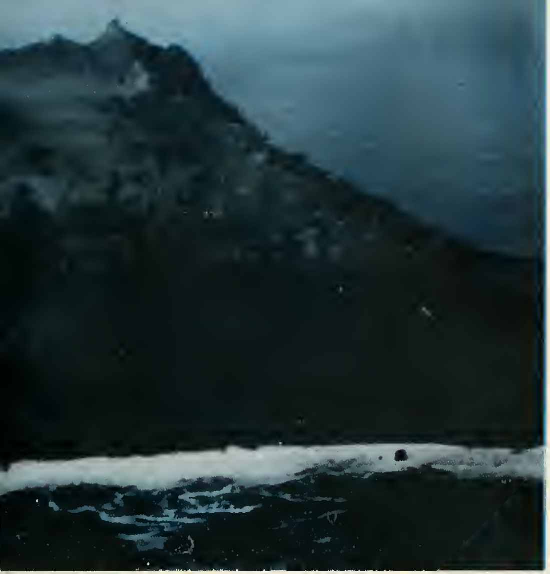
First phase of Darwin's theory assumes a solitary island, such as this one near Tahiti, providing a base for growth

Many of the most obvious questions about coral reefs are not easily answered. For example, is the living reef only a thin veneer over a platform of eroded older rocks? Or is it the summit of a pile of skeletons of marine organisms, maintained at sea level by deposition over a subsiding foundation? These questions—the subject of lively and, at times, angry debate for nearly a century—formed the basis of the celebrated "coral reef problem."

These questions now seem irrelevant. All living reefs are most probably thin growths resting on eroded surfaces of older rocks, some of which are fossil reefs. The West Indian reefs are most illuminating in this regard and they aid in a better understanding of all coral reefs.

In common with many geological processes, the growth

Final phase of classic subsidence theory is demonstrated, *above*, by the Tuamotu Archipelago atoll, Raroia, in which the central, volcanic island that provided a base for the growing reef has long since vanished, leaving a broad and



of reef corals in shallow water. Although this volcano is hundreds of years old, protective reef has not yet formed.

of coral reefs is too slow to be directly observed. Consequently, the history of a particular reef must be inferred from comparisons with other reefs in different stages of development, and from studies of the biology of reef organisms and the processes of erosion and sedimentation around reefs. The study method is almost wholly deductive, rather than experimental, and rests on a basic premise of historical geology—"the present is the key to the past."

THE principal reef theories advanced by early investigators were inferences based on scanty biological and geological evidence. Since many crucial facts were—and, indeed, still are—lacking, some of these classic theories were in conflict. However, it is now becoming clear, as is the case so often in science, not only that the truth about coral reefs is a synthesis of many ideas once regarded as irreconcilable, but also that no *single* explanation can account for *all* coral reefs.

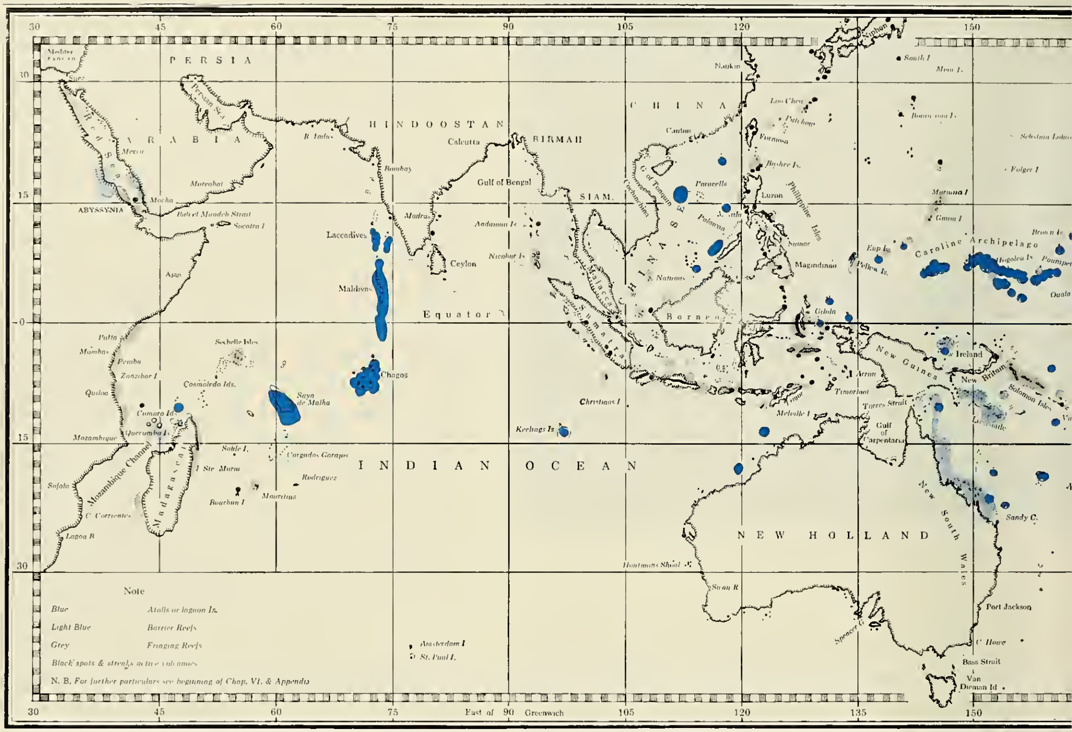
Charles Darwin's observations of coral atolls, both in the Pacific and the Indian Ocean, stimulated him to formulate his "subsidence theory"—universally recognized as a model of simplicity—along lines that had already occurred to him from what he had read of atolls. His *Structure and Distribution of Coral Reefs*, which appeared in 1842, was Darwin's first great work.

Reef corals and algae, Darwin declared, become established in tropical seas, in favorable places provided by shallow, sediment-free, rocky bottoms, frequently near the shore. If the sea floor subsides slowly, upward growth of the reef organisms may maintain the growing surface near sea level—the ceiling of growth for the reef-builders. Because growth is most rapid along the outer margin of a reef (and is inhibited along the shoreward margin by quiet waters, sediments and variable temperatures), the organisms occupying the inner part are unable to keep pace with subsidence. Thus, the outer, most rapidly growing part of the reef eventually becomes detached from the shore by a lagoon too deep or too muddy to support reef corals. Continued subsidence of a reef-encircled island leads to disappearance of the central island and formation of an atoll —a narrow ring of reef surrounding a lagoon that may range in maximum depth from about 30 to 250 feet.

Darwin was acquainted with geological evidence of uplift in mountain regions, and relative subsidence in sedimentary basins, but the geologists of his day did not have a satisfactory explanation of these phenomena. It is now known from studies of variations in gravity that the low areas of the earth's crust, such as the ocean basins, are underlain by relatively dense, heavy rocks, whereas the higher areas, such as mountain ranges and the continents themselves, are underlain by lighter rocks. The resulting gravity equilibrium—or isostatic balance—between high and low areas is disturbed by erosion and transfer of sedimentary load from one area to another, and by the growth of coral reefs and volcanoes, which locally overload the crust and cause isostatic sinking.

Darwin held that a coral reef might maintain its growing upper surface at sea level while the foundation slowly sank

shallow central lagoon. Dotting this lagoon are elliptical patch reefs, their shapes dictated by the prevailing wind direction. Seaward, beyond this atoll's quarter-mile-wide rim, the land rapidly disappears into mid-oceanic depths.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A R A B I A
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Ceylon
Maldivas
Gulf of Bengal
BIRMAH
SIAM
C H I N A
Nankin
Canton
Formosa
Luzon
Philippine Isles
Paracells
Borneo
Sumatra
Magindinao
Caroline Archipelago
New Guinea
New Ireland
New Britain
Solomon Isles
Gulf of Carpentaria
Torres Strait
Equator
Seschelle Isles
Chagos
Saya de Malha
Zanzibar I
Cosmoledo Ids.
Comoro Ids
Mozambique Channel
Madagascar
Mauritius
Bourbon I
Rodriguez
Cargados Garajos
Kerlings Is
Christmas I
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New South Wales
Sandy C.
Port Jackson
Bass Strait
Van Diemen Id
Swan R
Spencer G
Houtmans Shoal
Amsterdam I
St. Paul I.
Note
Blue — Atolls or lagoon Is.
Light Blue — Barrier Reefs
Grey — Fringing Reefs
Black spots & streaks active volcanoes
N. B. For further particulars see beginning of Chap. VI. & Appendix
East of 90 Greenwich
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to depths of thousands of feet—thus resulting in very thick reef deposits, even though the reef organisms are limited to water depths of less than three hundred feet (with an optimum at about fifteen feet).

Darwin's pioneer work on coral reefs quickly found strong support from a young genius of nineteenth century American science, James Dwight Dana, who recognized that the lower parts of the river valleys of many reef-girdled islands are drowned; that is, they plunge beneath the sea and the shores are deeply embayed where the valleys disappear. This suggested to Dana that the islands had sunk (or sea level had risen), since the valleys were eroded. With Dana's endorsement, Darwin's subsidence theory was accepted and the stage was set for a famous controversy.

DARWIN's explanation of atolls was incomplete, however, because it did not take into account the comparatively recent and great fluctuations in sea level produced by the waxing and waning of the Pleistocene continental glaciers. A new principal—that of the glacial control of coral reef formation—was introduced before the end of the nineteenth century by the German geologist Albrecht Penck and was greatly amplified by Professor Reginald Daly of Harvard University, one of the great figures in American geology, renowned for his originality.

Daly expressed the view that, at times of maximum glaciation, sea level must have been appreciably lower than the greatest depth of the present living reefs; that is, more than about 100 feet. Glacial cooling—and increased turbidity caused by wave erosion at the lowered sea level—killed off most of the reefs and deprived shores of the protection from erosion normally given by living reefs. He believed that erosion at the low glacial levels completely cut away small islands to form "banks," and produced broad erosional platforms around larger islands. As the glaciers melted and sea level and water temperatures slowly returned to normal, river valleys were drowned, the most favorable areas at the exposed edges of the erosional platforms were recolonized by corals, and new reefs grew upward about as rapidly as the rise in sea level. According to this theory, all living coral reefs are very young—less than ten thousand years old—and extend no deeper than the level of the lowest stages of the Pleistocene sea, say 450 feet below present sea level.

Daly's glacial control theory enjoyed great popularity for many years and the essential importance to coral reefs of the effects of Pleistocene cooling and fluctuations of sea level is now well established. His case was weakened, however, by his insistence that great subsidence has not been involved in the origins of *any* living reefs.

During the three decades before World War II, the subsidence theory was vigorously attacked by many leading authorities on coral reefs, especially Daly, Vaughan and

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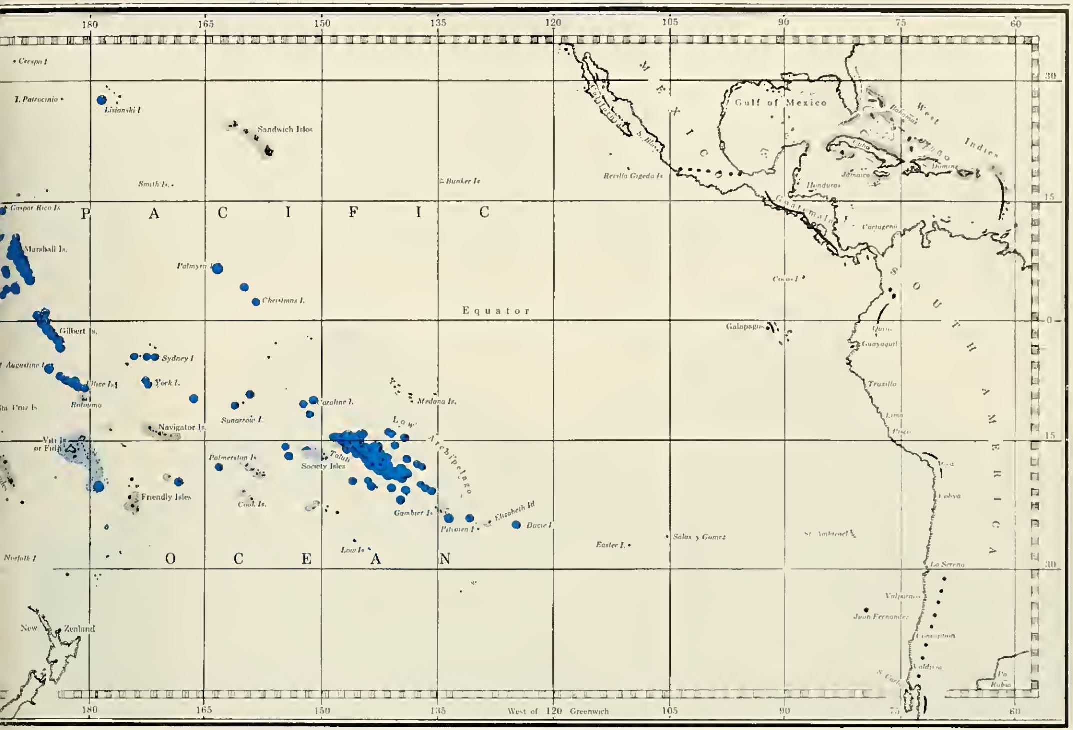
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Crespo I
I. Patrocinio
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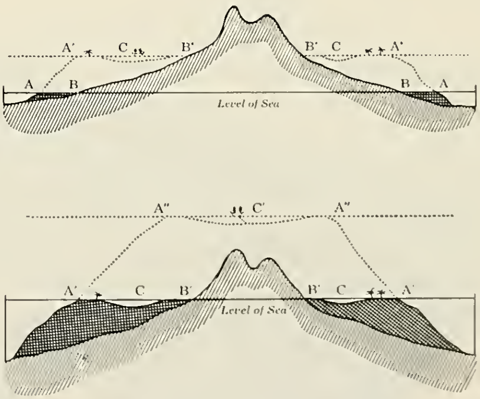
Smith Is.
Bunker Is
Revillo Gigedo Is
Gulf of Mexico
West Indies
Cuba
Jamaica
Domingo
Honduras
Guatemala
Cartagena
Gaspar Rico Is
P A C I F I C
Marshall Is.
Palmyra I.
Christmas I.
Equator
Cocos I
Galapagos
Quito
Guayaquil
Gilbert Is.
Sydney I
York I.
Augustine I.
Ellice Is.
Rotuma
Sta Cruz Is
Caroline I.
Mendana Is.
Low Archipelago
Sunarrow I.
Navigator Is.
Viti Is or Fiji
Palmerston Is
Tahiti
Society Isles
Friendly Isles
Cook Is.
Gambier Is.
Pitcairn I.
Elizabeth Id
Ducie I
Easter I.
Salas y Gomez
St Ambrose I.
Truxillo
Lima
Pisco
Arica
Cobija
La Serena
Valparaiso
Juan Fernandez
Concepcion
Valdivia
S. Carlos
Norfolk I
O C E A N
SOUTH AMERICA
New Zealand
West of Greenwich

Darwin's chart of the world's coral reefs, copied *above*, divided them into three groups: atolls (blue); the barrier reefs (light blue); and fringing reefs (gray). Black spots and lines indicated volcanoes then active. Plotting showed that most atolls and barrier reefs lie outside continental shelves. West Indian reefs were set down as fringing ones.

Gardiner, and a great forward step was made during this period by William Morris Davis, who stressed a fundamental difference between the oceanic reefs of the Indo-Pacific region, on the one hand, and the marginal belts of coral seas in the West Indies and elsewhere, on the other. Davis applied physiographic principles to the coral reef problem, as had Dana, concentrating his attention not so much on the reefs themselves as on the comparative differences between the cliffed shores of reef-free areas and the much less eroded, reef-protected shores. He demonstrated that the effects on coral reefs of the sea-level shifts of the Pleistocene glacial stages were great along the continental margins, but negligible in the deep-water basins of the tropical Pacific and Indian oceans.

Davis showed how slow subsidence and, to a lesser degree, glacial changes in sea level had affected the great reefs of mid-ocean. At the same time, he pointed out that a majority—possibly all—of the pre-Pleistocene coral reefs in the West Indies and certain other "marginal" areas had been killed by the onset of the glacial changes. The living West Indian reefs—cited by Agassiz, Daly, Vaughan and others as evidence against Darwin's subsidence theory—are, in fact, postglacial and so young that for the most part they have not been involved either in measurable subsidence or in large changes in sea level. Hence, Davis declared, they are not closely comparable to the really old barrier reefs and atolls of the western Pacific. Davis' may be termed the "synthetic" theory of coral reefs: it tailors the explanation to the local situation.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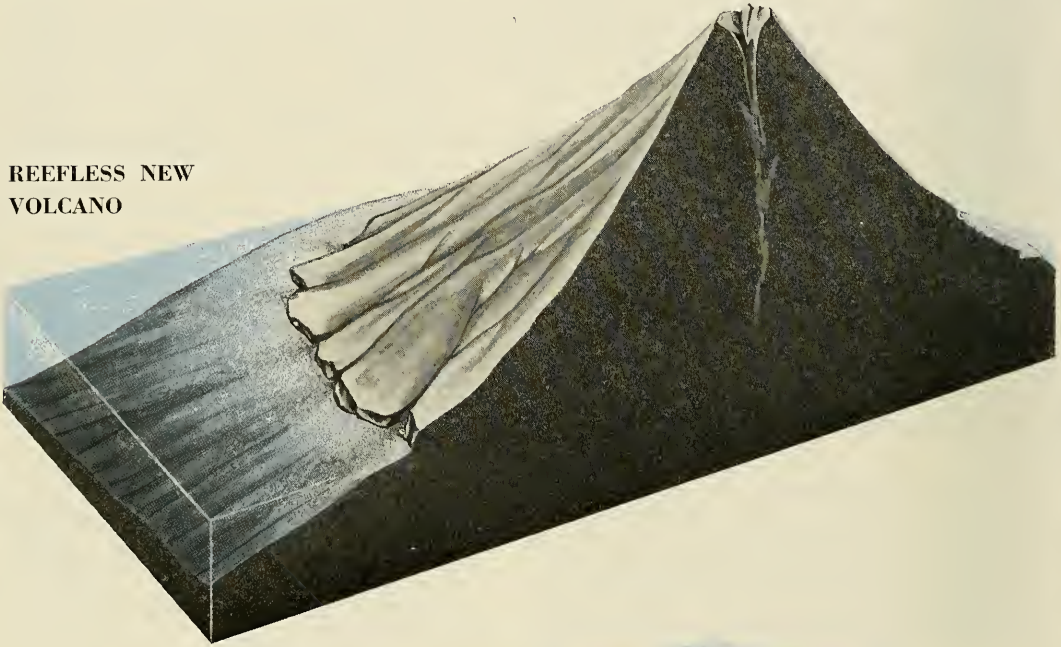
Darwin diagrammed his concept of reef evolution, *above*. He held that coral growth kept abreast of a constant sea level as island subsided, to produce a barrier reef and a lagoon in early phases (top) and finally an atoll (bottom).

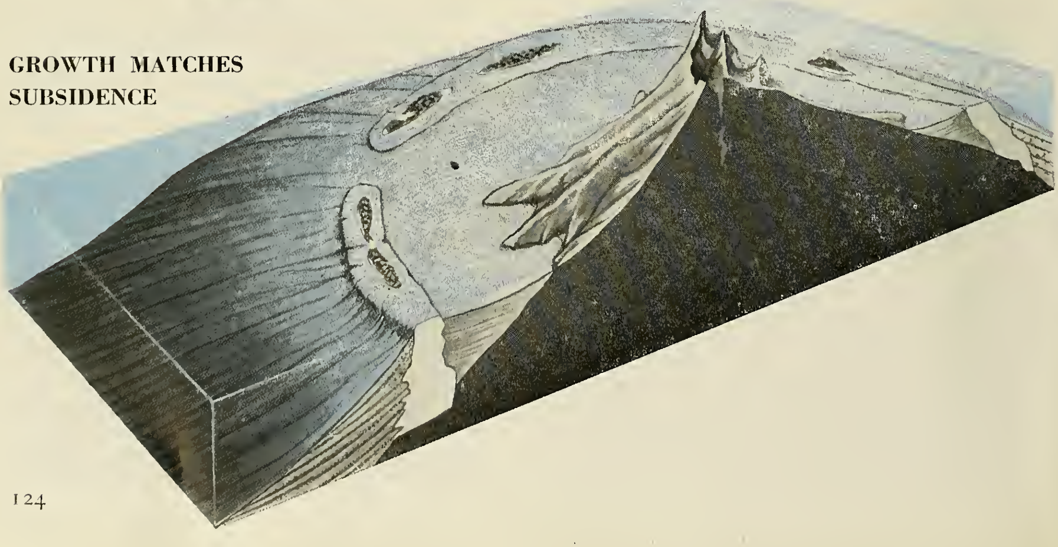
DARWIN EXPLAINED OCEANIC

THE MOST USEFUL SCIENTIFIC THEORIES are simple. but also adequate. explanations of natural phenomena. As regards this yardstick, Darwin's explanation of coral reefs —as stages in a continuous evolutionary sequence. leading from fringing reefs to atolls—has long been considered an outstanding model. Well before Darwin. it was known that coral reefs are limestone prominences on the sea floor, built upward by the gradual accumulation of the skeletons of shallow-water corals and algae. Darwin knew that many reefs rise to the surface from very deep waters. extending far below the range where reef organisms can live. He concluded that the foundations of these reefs must have been sinking. while the upper portions grew upward—maintaining a position near sea level. Both the form and structure of reefs, Darwin held. could best be explained as a consequence of such upward growth during slow

1. REEFLESS NEW VOLCANO



3. GROWTH MATCHES SUBSIDENCE

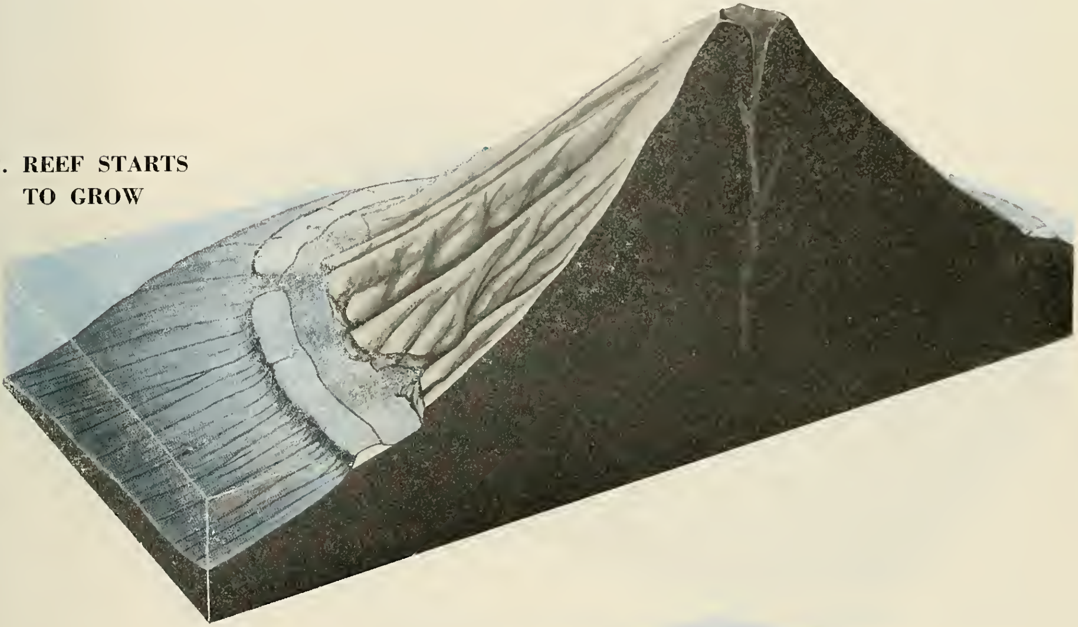


CORAL REEFS BY SUBSIDENCE

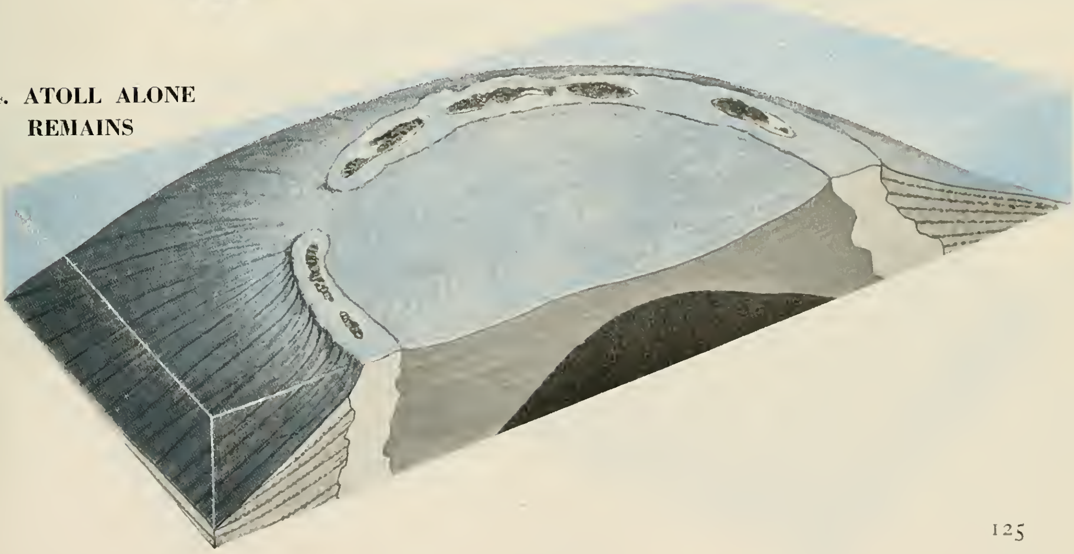
subsidence. As diagrammed, *below*, Darwin recognized four main stages in reef evolution: a reefless, new island; a fringing reef; a barrier reef; and, finally, an atoll.

COLONIZATION of a new island's shore would be inhibited, at first, by erosion and sediments. But, eventually, a fringing reef would be established, protecting the shore from further wave erosion. Reef corals grow rapidly under favorable conditions: this growth keeps them close to sea level despite the island's persistent sinking. Subsidence, combined with upward reef growth, brings separation of the reef from the shore—in barrier form, enclosing a lagoon—and, finally, complete submergence of the central island, leaving only lagoon and atoll reef visible. For the more complex picture of reef growth along continental margins, where folding and uplift are common, turn the page.

2. REEF STARTS TO GROW



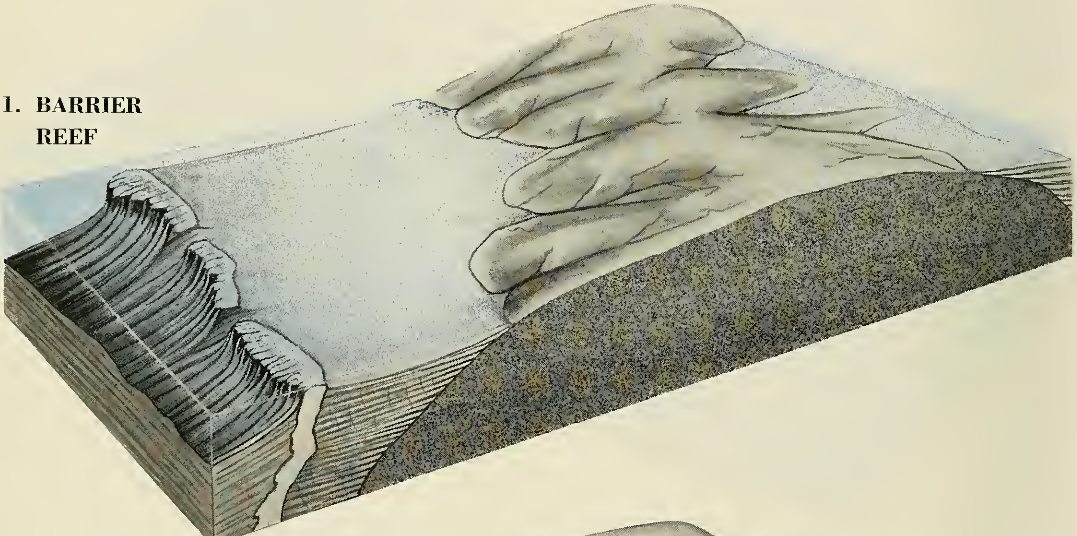
4. ATOLL ALONE REMAINS



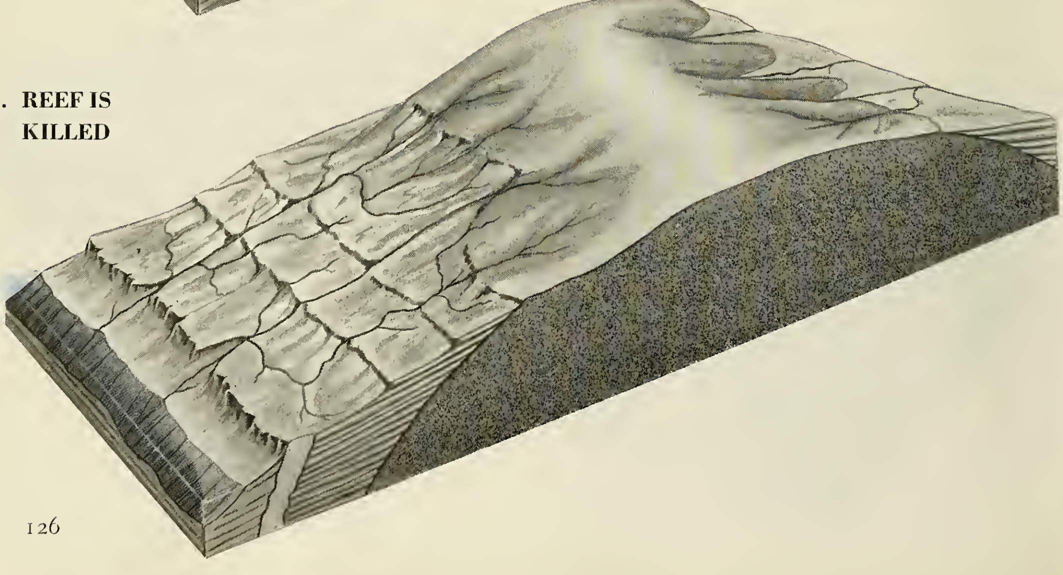
DALY STRESSED THE GLACIAL

Forty years ago, Reginald Daly pointed out that all preglacial coral reefs must have been exposed to the air and killed, as the fluctuating sea level reached new lows during the times of continental glaciation. In the tropics, shore lines previously protected by reefs would thus have been deprived of protection and eroded and planed by wave action to the new, low levels of the sea. The submerged terraces and banks over which present reefs grow, Daly believed, are the eroded stumps of preglacial reefs. William Morris Davis, in turn, demonstrated that destruction and erosion of the coral reefs during these times of fluctuating sea level were not particularly severe in the deepest parts of the tropical oceans, far removed from the influence of continental climate. Near the continents, however, as in the case of the West Indies, Davis found that the destructive effects were marked. These influences—of changes in sea level and of glacial cooling—are shown in the Virgin Islands, *below.*

In this region, subsiding volcanic islands were originally flanked by protective barrier reefs and shallow lagoons. With the onset of Pleistocene cooling and withdrawal of the sea, broad limestone coastal plains—with



1. BARRIER REEF



3. REEF IS KILLED

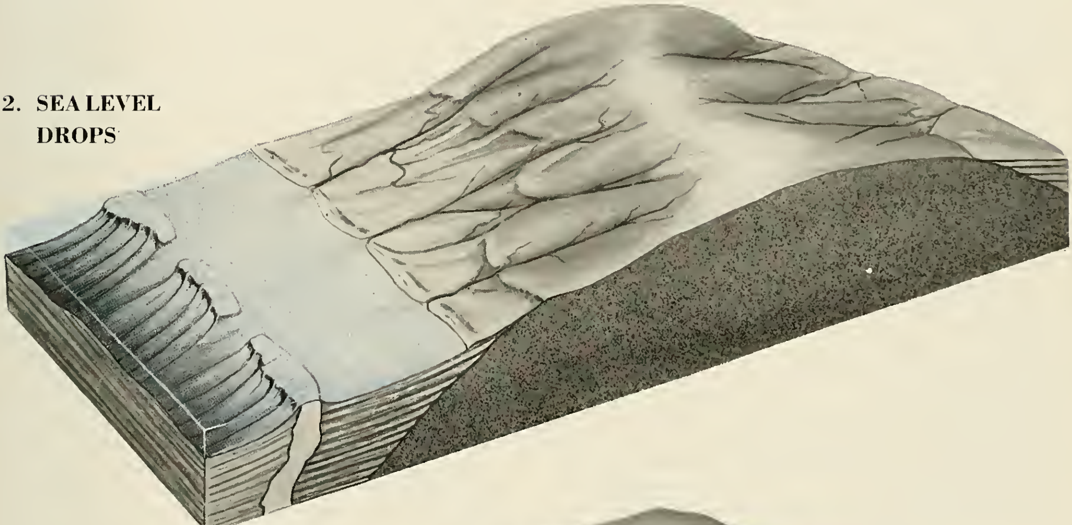
FACTORS CONTROLLING GROWTH

successive beach ridges and dunes—were exposed. The old barrier reefs were exposed and killed and the reef organisms were unable to re-establish a protective cover at these lower levels because of prevailing low temperatures.

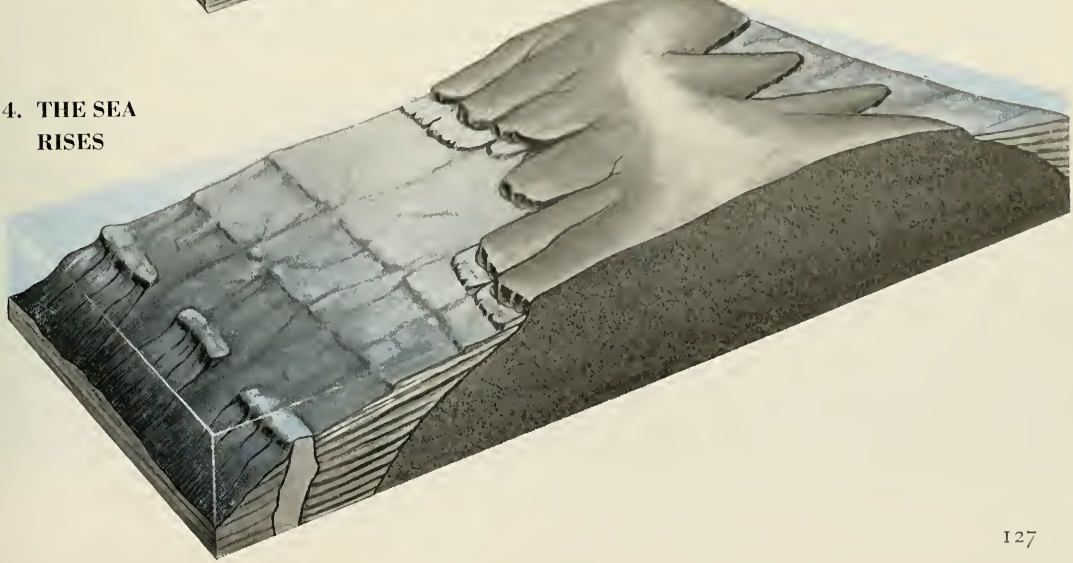
Melting of the continental glaciers and the rise of sea level to its present position, in turn, left traces of the old, cemented beach ridges—as rows of bottom prominences. Subsequent shore erosion of the volcanic islands was retarded by the establishment of very young, fringing reefs in shallow waters along the crests of the old, submerged beach ridges. These new reef growths agree in general form with barrier reefs. Other new reefs have grown from the rocky shoals adjacent to the islands' cliffed headlands.

DALY'S THEORY explains the extensive submarine terraces found in areas now marked by young and feeble fringing reefs. But, as Davis has shown, the limestone banks are, for the most part, ancient, drowned barrier reefs and lagoons—formed *before* the Pleistocene glaciation. Thus, a synthesis of Darwin's subsidence theory and Daly's glacial control theory is required to explain the features of many coral reefs in the West Indies.

2. SEA LEVEL DROPS



4. THE SEA RISES



Since World War II, there has been a great revival of interest in coral reefs, sparked by the discovery of independent evidence about reef origins—evidence that could be obtained only by deep borings completely *through* the reefs to their underlying "basement." "I wish," Darwin had written, in the year preceding his death, to the American oceanographer Alexander Agassiz, "that some doubly rich millionaire would take it into his head to have borings made in some of the Pacific and Indian atolls, and bring back cores for slicing from a depth of 500 or 600 feet." The wish was realized, many years later, to an extent beyond Darwin's dreams. Two deep borings, completed on Eniwetok atoll in 1952, finally reached a volcanic basement below reef limestone, but not until they had reached a depth of over four thousand feet. Thus Darwin's conclusion that atolls of the central basin of the Pacific Ocean rest on a subsiding foundation was finally confirmed. Eniwetok has subsided at an average rate of two millimeters each century for the past sixty million years.

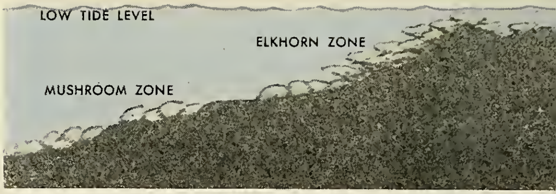
Fathometer soundings in the Pacific have also revealed the existence of hundreds of deeply submerged, flat-topped volcanic mountains, called "guyots," some of which are crowned by limestones and shallow-water fossils drowned millions of years ago by too rapid subsidence. The flat tops are interpreted as wave-eroded platforms, cut across newly formed volcanoes before they sank under the sea during Cretaceous and early Tertiary times. Some guyots have also been identified on the floor of the Atlantic Ocean.

Both these new findings make it clear that Darwin was basically right about the reefs of the deep oceans, and that his opponents went too far in denying that subsidence was an essential factor in the formation of the typical atolls and barrier reefs in the deep-water areas of the Indo-Pacific region. The discoveries of modern geophysics show that the crust beneath the oceans is relatively heavy, as compared to the continental areas, and we are no longer surprised that large areas of the ocean basins should be characterized by long-continued subsidence. The border areas between oceans and continents, on the other hand, are influenced by continental climate and terrigenous sedimentation, and they contain belts of crustal warping and folding. It is precisely in these areas that many of the coral reefs do not conform so well to the Darwinian concept of reef evolution by persistent subsidence.

By far the greater part of scientific work on coral reefs has been done in the deeper parts of the Indian and Pacific Oceans, and this fact has strongly colored our views. These reefs have many features in common that distinguish them from West Indian reefs, and a consideration of the differences between the two areas aids in drawing conclusions about the fundamental nature and genesis of all coral reefs. Let us briefly compare reefs of the two areas.

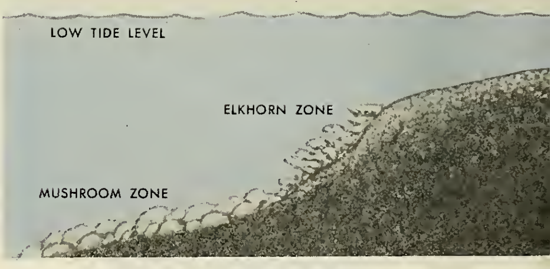
The classic reefs of the Indo-Pacific area rise through thousands of feet of water just to the surface of the sea. Because they are formed of cemented skeletons, their upper slopes exceed the angle at which loose gravel or sand will come to rest, and the outer, advancing rim of the reef may descend as a sheer cliff for hundreds of feet. An average slope of 60° or 70° is not uncommon for the upper part of these coral reefs.

At low tide, on a very quiet day, an observer on the reef edge can look down into unbelievably transparent, blue waters with a sensation of height, as though looking down from a cliff. When Captain Cook was exploring along the Great Barrier Reef of Australia, he found that he could not touch bottom with two hundred fathoms of line, although his ship stood within fifty yards of the reef edge. There are depths of a mile here, within half a mile of the reef.

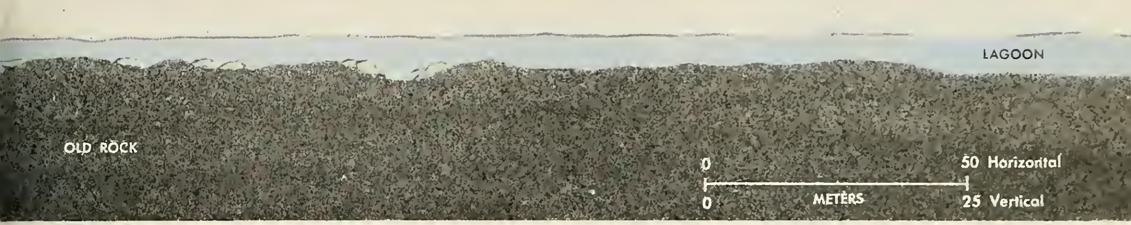


West Indian reef, typical of bank margins, is shown here in cross section, sloping seaward at left. Living coral is

Large areas of the reef top, emergent or just awash at low tide, resemble a rough concrete slab, a few hundred yards wide, that extends as far as the eye can see. Only the hardiest reef organisms can stand daily exposure to the sun and air of the reef flat and the first impression, here, is one of desolation. Toward the seaward edge, where breaking waves continuously bathe the reef flat, the surface is covered by low corals and a pinkish, hard crust—formed by lime-secreting algae of the Lithothamnion group. At the very edge of the reef, the algal deposits form a low, hummocky ridge, which is very resistant to wave erosion. It has long been recognized that the surface of the inner part of the reef flat is an erosional plain—cut approximately at low tide level in previously elevated reefs and island deposits. It does not follow that all of the erosion is of recent date. Most probably, the reef flat lies not far from the normal interglacial level of the sea. The outer part of the reef flat is not an erosional surface, however: it is built up by the calcareous secretions of the hardiest species of corals and algae—organisms that can resist wave shock and stand exposure a few inches above low tide level, bathed by the splash of breaking waves. The reef platform is protected from wave destruction by the algal ridge. Without it, the flat would be destroyed about as fast as it forms.



Polynesian reef, typical of the Indo-Pacific region, is shown, *above*, for comparison. This is Raroia. Notable features are



only a thin veneer which fails to obscure submerged beach ridges formed during lower stands of sea level associated with glacial periods. This is Love Hill, at Andros, in the Bahamas. Vertical scale has been made twice the horizontal.

Small patch reefs commonly occur in the sheltered lagoons. They possess neither algal ridge nor reef flat. The upper surface corresponds to the tops of living corals, growing in water a few feet deep at low tide. Unlike the main reefs, many of which evidently are being cut down from higher levels, the solid interior of the patch reefs does not reach low tide level and there is no indication that they have been cut down from a higher level. These facts suggest that the patch reefs may generally be younger than the large seaward reefs.

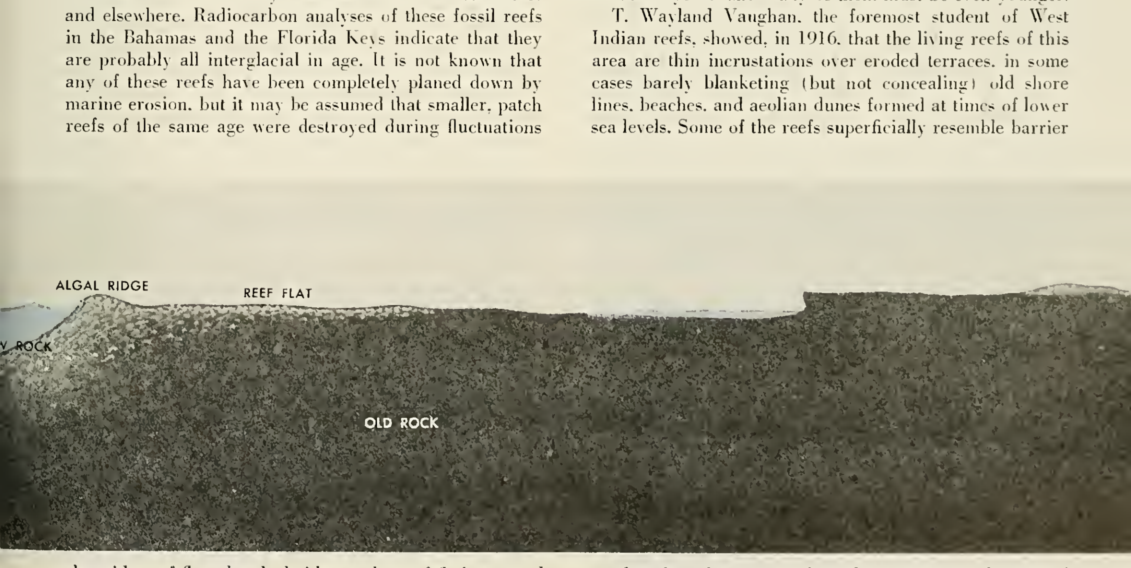
What, in contrast to this classic picture, do we see in the West Indies? By way of preface, it is generally accepted by geologists that sea level was appreciably higher during the last interglacial stage (some 100,000 years ago, when the polar ice caps apparently lost most of their ice) than it is today. Many believe that sea level was also higher three to four thousand years ago, but this contention is not yet established by unequivocal evidence, and is unsupported by observations in the tropical Atlantic.

Fossil coral reefs some five to fifteen feet above present low tide level, are widely distributed in the West Indies and elsewhere. Radiocarbon analyses of these fossil reefs in the Bahamas and the Florida Keys indicate that they are probably all interglacial in age. It is not known that any of these reefs have been completely planed down by marine erosion, but it may be assumed that smaller, patch reefs of the same age were destroyed during fluctuations of sea level. The present patch reefs of the West Indies are clearly postglacial in age.

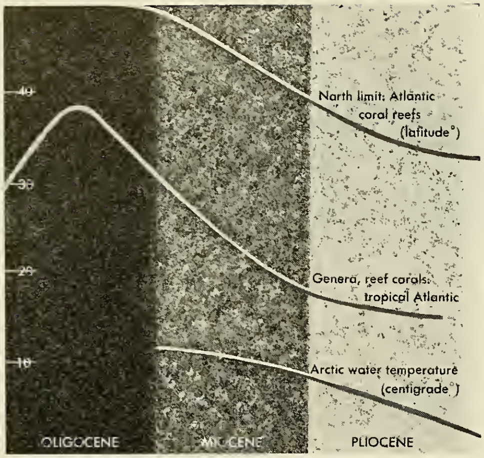
Even a casual inspection of West Indian reefs shows that they are not like the seaward reefs of oceanic barriers and atolls. They form fringes along shoals, and rocky shores remote from the outer edges of deeper rock platforms and they never lie adjacent to deep waters. At their seaward edge, these reefs rarely extend into water sixty or seventy feet deep: below sixty feet, the gently sloping platforms bear only scattered heads of massive corals, occasionally bunched to form low knolls.

A majority of the West Indian reefs are confined to the windward sides of banks and islands and very few are exposed at low tides. Algal deposits are generally not important and considerable damage is done to the reefs during great storms and horizontal growth toward the open sea is everywhere greatly retarded. From every indication, the West Indian reefs were formed at present sea level and they have not been appreciably affected by either crustal movements or changes in sea level. Thus, their maximum probable age cannot be greater than four to five thousand years, and many of them must be even younger.

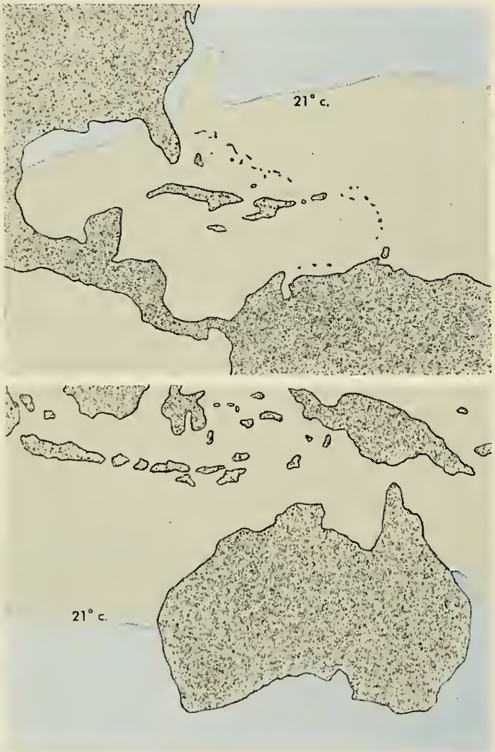
T. Wayland Vaughan, the foremost student of West Indian reefs, showed, in 1916, that the living reefs of this area are thin incrustations over eroded terraces, in some cases barely blanketing (but not concealing) old shore lines, beaches, and aeolian dunes formed at times of lower sea levels. Some of the reefs superficially resemble barrier



the wide reef flat; the algal ridge at the reef flat's seaward margin; terraced profile of the whole. Most of the corals are found on the seaward slope, *left*. Postglacial deposits of coral are probably very thin. Scale is same as at Love Hill.



ATLANTIC CORAL REEFS' decline during past fifty million years is indicated by parallel graphs, *above:* shrinkage of tropical reef zone; a loss of some coral genera; isotopic evidence of ocean cooling (data from Wells and Emiliani).



EFFECTIVE LIMIT for reef corals, north and south of the equator, is provided by an average water temperature of 21° C., or higher. Thus, the West Indian and Australasian reefs extend for about the same distance from the equator.

reefs, while others, simulating atolls, form fringes around circular shoals. But generally they are too thin to mask the character of the underlying topography or even to conceal the underlying rocks. Vaughan judged the reefs to be only a few hundred years old, an estimate based on present growth rates of reef-forming corals.

The best-developed reefs of the Bahamas, Jamaica and Florida usually show three principal biotic zones—controlled, apparently, by differing conditions of turbulence and light at different depths. These are: an outer belt of massive corals, especially *Montastrea annularis,* lying at substrate depths between about thirty and sixty feet; an intermediate belt of elkhorn corals, *Acropora palmata,* in turbulent waters between about five and thirty feet; and an inner, rocky shoal—rising to the lowest tide level and characterized by the stinging hydroid, *Millepora alcicornis,* incrusting algae, seafans, and small massive corals.

Low islands of the West Indies, like those of the tropical Indo-Pacific region, are generally formed of limestone, and a majority of the high islands are volcanic or are composed of folded sedimentary and metamorphic rocks. Both kinds of islands in the West Indies are commonly surrounded by broad, shallow platforms (or "banks") of limestone with steep marginal slopes. Shallow banks, with or without islands, lie near the surface at many places in the Caribbean, the Bahamas and along the mainland coasts. They generally rise toward the shore in a series of low benches or steps from marginal depths of anywhere between twenty and sixty fathoms. Along reef-free rocky shores, the bottom lies near the maximum depth of strong wave abrasion, between about three and six fathoms.

NUMEROUS investigations of the continental shelf have been made along the north edge of the Gulf of Mexico since World War II. These have made use of automatically recording echo-sounding instruments, dredged samples and sediment cores. It is now known that mysterious pinnacles and ridges occur along the edges of submerged erosional terraces down to about sixty fathoms. These have been regarded as dead reefs, formed at low levels of the Pleistocene sea. It was thought that sea level rose so rapidly, while the glaciers were melting, that the reef organisms were unable to maintain a growth position near the surface and the reefs had been drowned.

Dredged samples do not support this interpretation, however. The rock of the pinnacles and the associated loose sediment only rarely contain examples of the principal West Indian reef-forming coral species. It seems probable that the northern part, at least, of the "West Indian province"—as the tropical, western Atlantic is called by biogeographers—was too cold for reef corals during these glacial stages, and that tropical biota did not become reestablished in the Bahamas and in Florida until quite recently, perhaps only three to four thousand years ago.

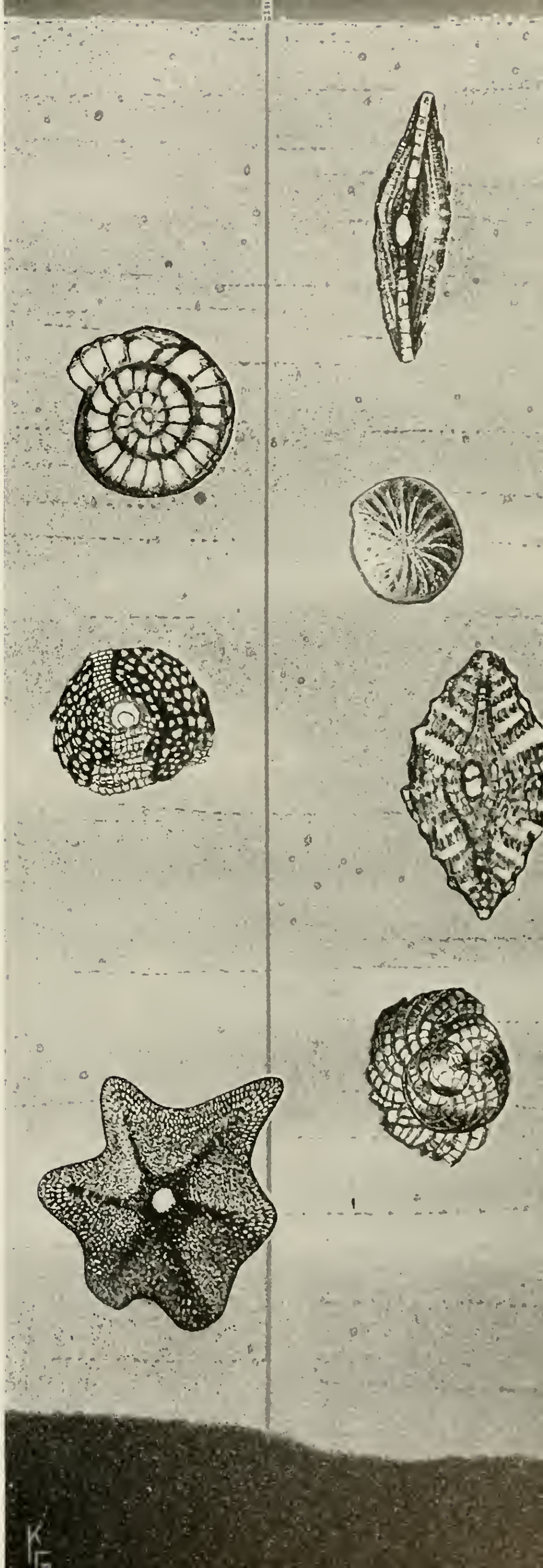
A more plausible explanation of the shelf-edge pinnacles and ridges is suggested by examination of the visible rocks of the islands of Bermuda, the Bahamas, and many of the offshore cays of Cuba, Puerto Rico and other areas throughout the West Indies. A few of these islands are formed of fossil coral reefs, but the majority are cemented beach and dune ridges, formed along successive shores of the fluctuating Pleistocene sea. Some of these old shore ridges, now submerged below sea level, rarely bearing scattered, dead, reef corals, may be identical in character with the exposed ridges.

The West Indian province is isolated from other tropical regions. Because of this isolation, it contains distinctive animals and plants, and our knowledge of the manner in which West Indian biota came into existence is one of the triumphs of paleontology. The fossil record shows that, before the Miocene epoch, the West Indies sea was populated by organisms similar to those of the Indo-Pacific and Mediterranean regions. Gradually, during the Miocene epoch (some twenty million years ago), the shallow-water forms of the western Atlantic were cut off on the east by a land barrier between the Mediterranean and Indian Oceans—and probably by deepening of the central Atlantic basin. Finally, during the Pliocene epoch (some six or eight million years ago), the Central American isthmus rose above the sea, completely separating the Caribbean from the Pacific Ocean.

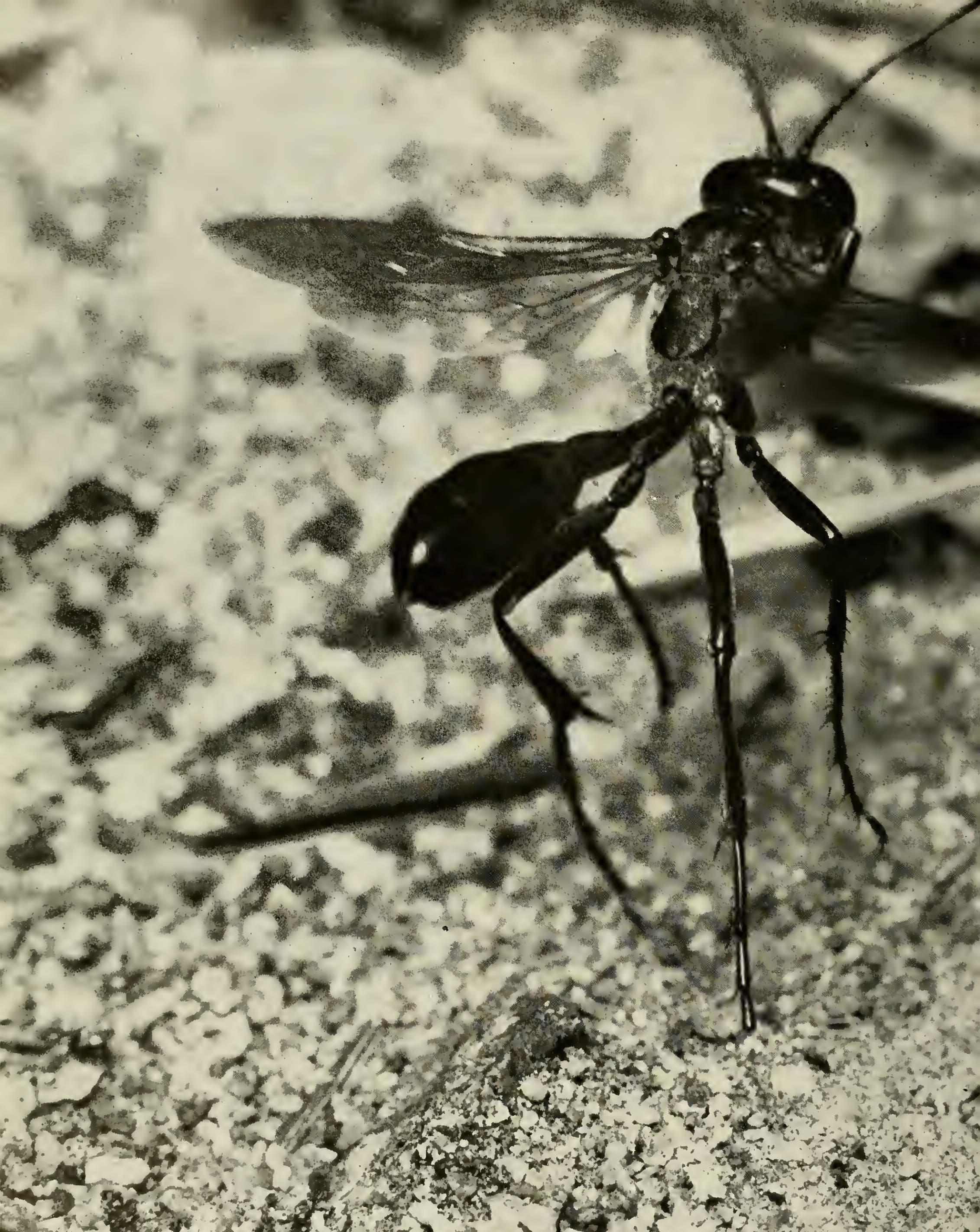
Subsequent history of the West Indies has been characterized by a dwindling in the number of species of marine organisms. In contrast, the organisms of the much vaster Indo-Pacific region, with more varied ecologic opportunities, have become progressively more diversified. The climax for West Indian corals (and probably the time of greatest reef-building) was during late Oligocene and early Miocene times, some twenty to thirty million years ago. Since those times, Atlantic reef corals have been on the decline. The northern limit of coral reefs in the whole Atlantic region has gradually shrunk toward the equator.

Unfavorable changes in climate and sweeping alterations in the physical environment of the region generally have been deleterious for reef corals. The West Indian region was disturbed at the beginning of the Tertiary, and again late in the Miocene, by widespread mountain uplifts—resulting, both times, in widespread deposition of muddy sediments in the adjacent seas. These various factors—restriction of the West Indian area through isolation and cooling, and regional increase in the turbidity of the waters—have added up to a general deterioration of the West Indian reefs as compared to the mid-oceanic reefs of the Indo-Pacific, far removed from the influence of harsh continental climate and sedimentation.

It is strange that the ups and downs of Pleistocene glaciation—which, according to Emiliani, may have cooled the Caribbean surface waters by as much as 5°C. below present temperatures, causing vast regional contraction of the area of the West Indian biota—did not cause wholesale extinctions among the coral species. Instead, the fluctuations of sea level caused by the growth and melting of the continental glaciers may actually have stimulated the evolution of new coral species. One-third of the species of reef corals now living in the West Indian region are not known as fossils. However, this discrepancy may be attributable to nonpreservation or inadequate search for fossils. While the Pleistocene climatic changes evidently did not deplete the West Indian reef community, the great fluctuations in sea level—ranging from four hundred and fifty feet below to some tens of feet above present sea level—did determine the sites favorable for reefs and greatly affected their modes of growth. (The second part of Dr. Newell's article will appear in NATURAL HISTORY's issue of April, 1959).



DEEP BORING at Eniwetok, *right*, finally reached volcanic rocks only after penetrating more than four thousand feet of reef deposits. Date of origin, established by Foraminifera, *inset:* in the Eocene, about sixty million years ago.

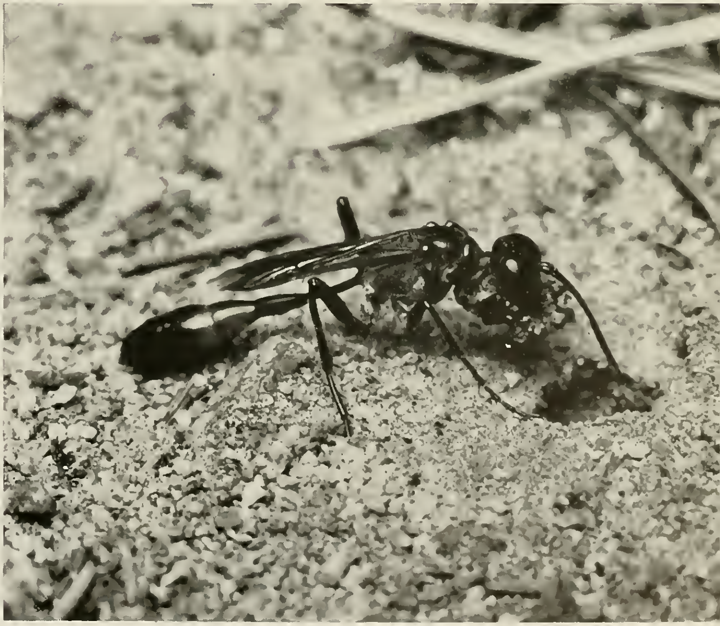


Thread-waisted sphex, blue or black with orange or reddish band near middle of abdomen, is among most graceful of all wasps. Genus is found in all parts of the world; commonest North American species are *procera, urnaria* and *vulgaris.*

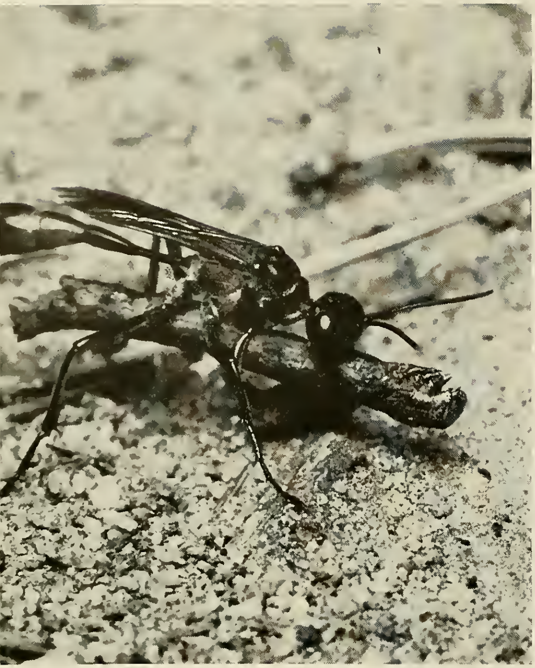
PREDACEOUS SPHEX

To provide food for its offspring in the nest, this beautiful solitary wasp paralyzes its prey

The Sphecidae comprise a family of solitary wasps, for the most part diggers who provision their tubelike nests with a wide variety of the larvae of other insects for their own larvae and pupae to feed on. *Sphex*, the wasp seen here, is among the best-known members of the family and, as students of this genus have remarked, this slender creature, blue or black with an orange or reddish band near the middle of the abdomen, is among the most graceful of all wasps. The Sphecidae either kill or paralyze the prey with their sting. If the prey is killed, the poison must have antiseptic properties too, since the victim's tissues remain fresh enough to be eaten in the nest for weeks. *Sphex*, for its part, merely paralyzes its prey. The victim is stung repeatedly, but observers' attempts to reduce the stinging actions to some pattern have not been successful, and it would seem that the stinging is random. It is often said, also, that the prey's nerve centers specifically are stung, but this is an inference, not fact.

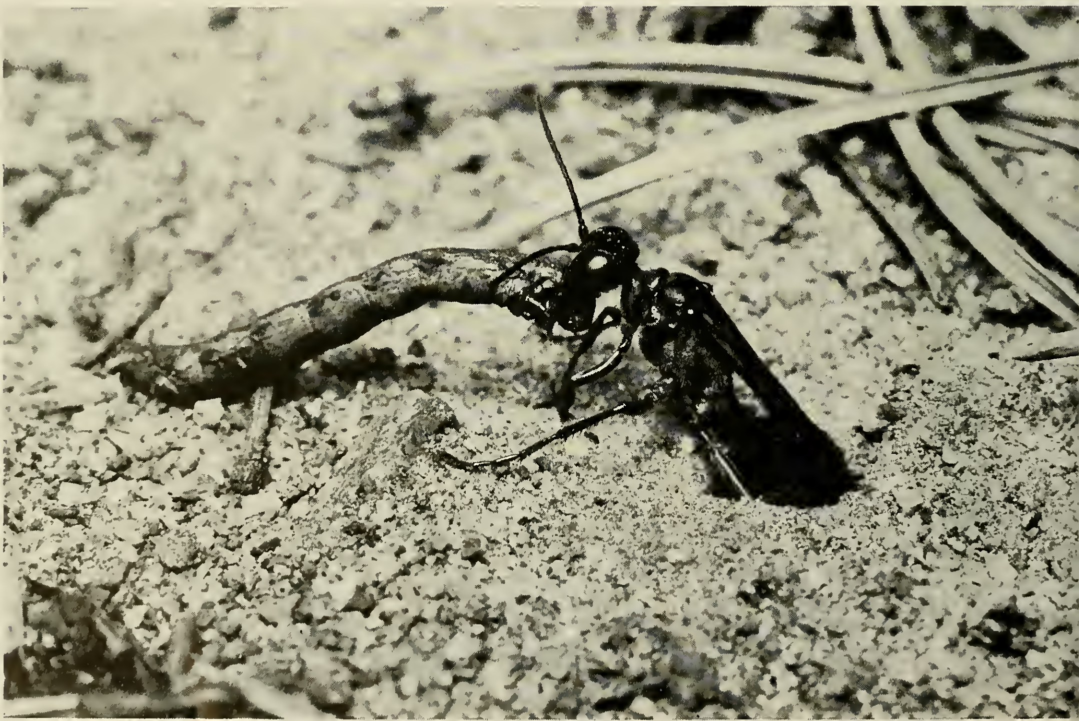


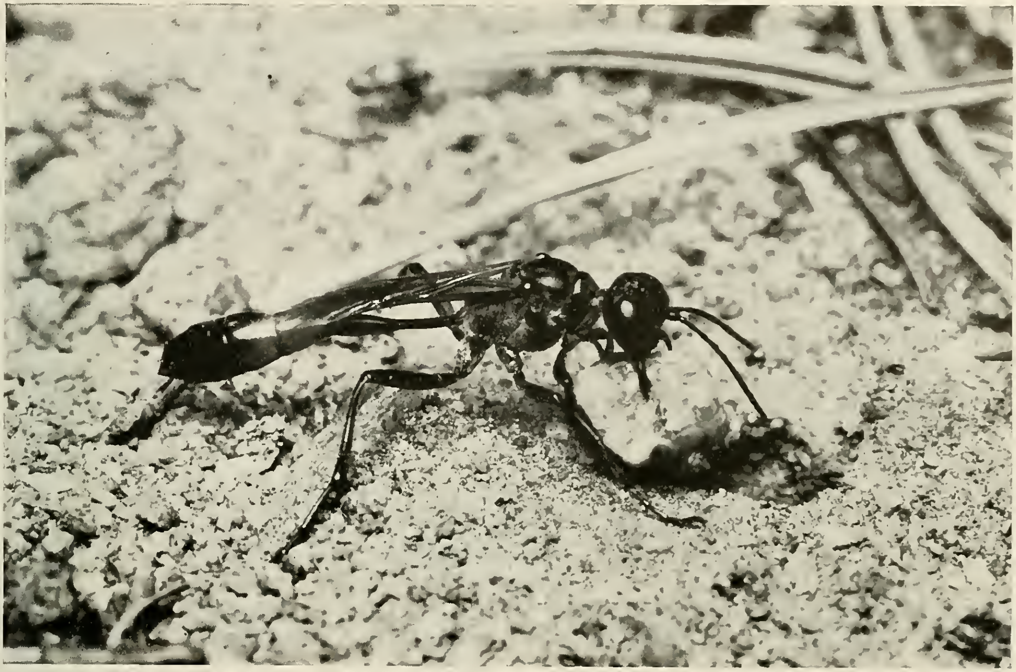
Digging a nest, the female *Sphex* makes tunnel ending in a cell for her larva.

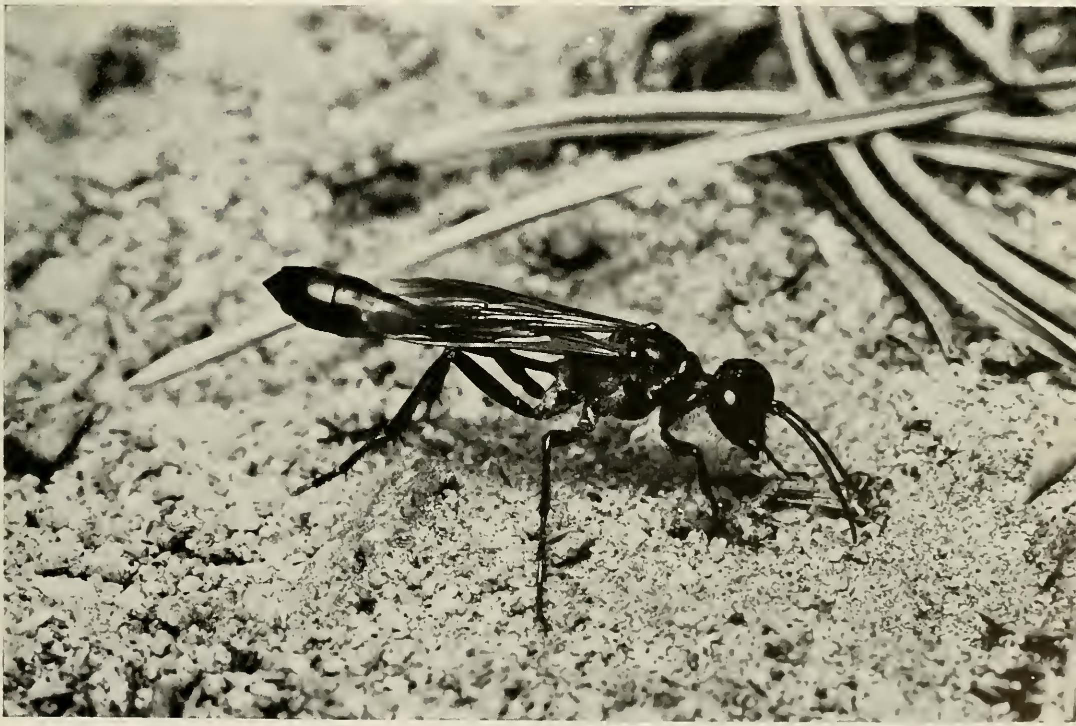


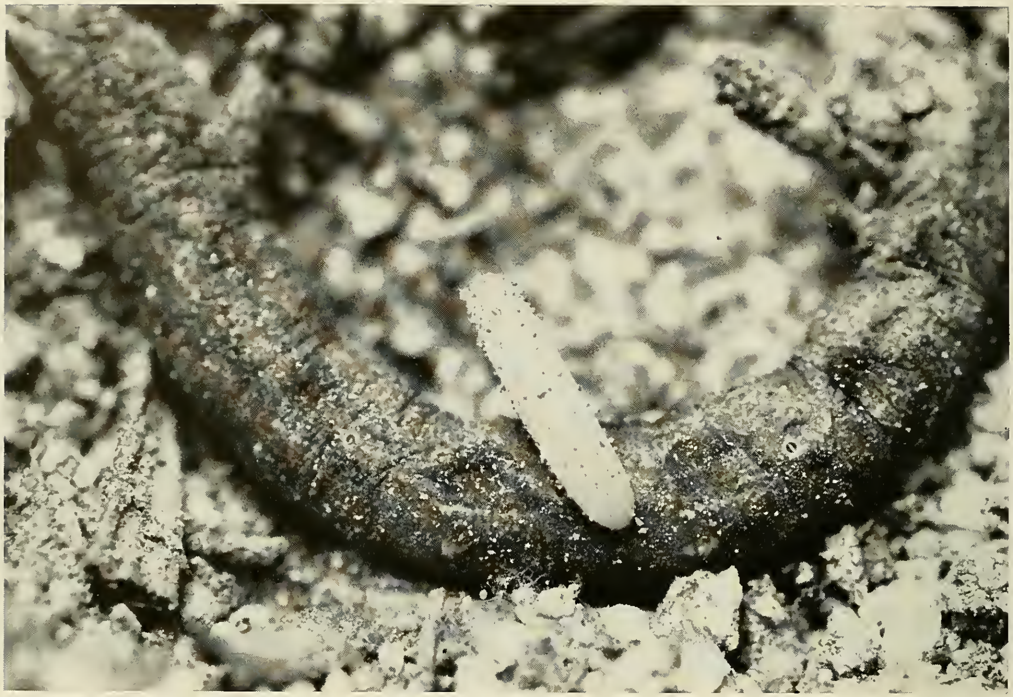
Sphex in action

THE VICTIMS *Sphex* takes are of the Order Lepidoptera—butterflies and moths; and, like the larval wasp they nourish, they are larvae themselves. In the present case, *left*, the prey is a measuring worm. In others, it may be a cutworm, and this occasions one of *Sphex*'s most remarkable feats, for nocturnal cutworms bury themselves in the soil by day; yet the wasp is able to locate them all the same. *Sphex*'s own nest—a tunnel which ends in a single cell—is virtually impossible to detect, and only when a victim is being dragged to it or when *Sphex* is digging can it readily be found. Usually, *Sphex* digs her nest and only then goes in quest of food for her larva, closing the nest and smoothing the surface soil as she goes, *lower right*—although the food may be got before digging. She sometimes uses a pebble to pound the soil over the mouth into a tight plug, *top right*. But whenever she leaves her nest, inhabited or not, the adult closes it to prevent flies from depositing maggots inside. These grow faster than *Sphex* larvae—which they eat.

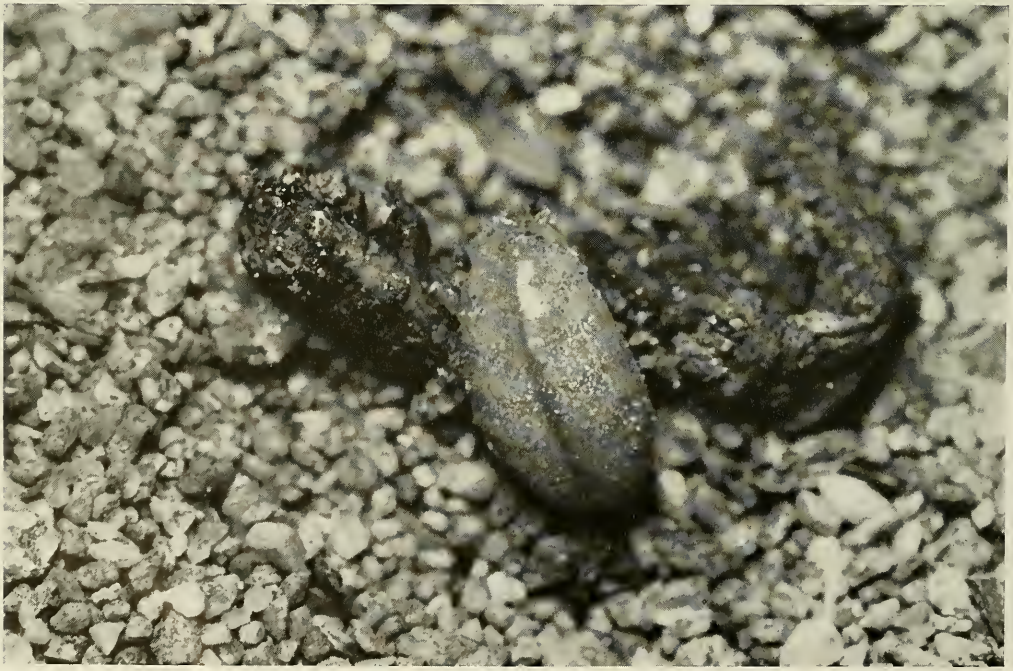








Sphex larva is shown, *above*, with a newly deposited worm for it to eat. By the time larva has grown to pupal stage, *at bottom*, food has been largely eaten. Remarkable series of photos is work of Swedish nature photographer Nils Gonnert.



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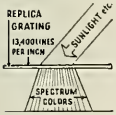

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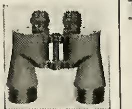

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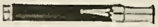

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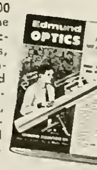

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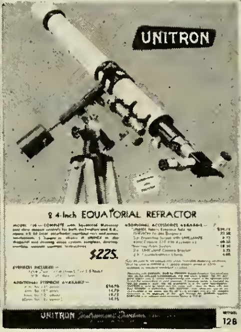
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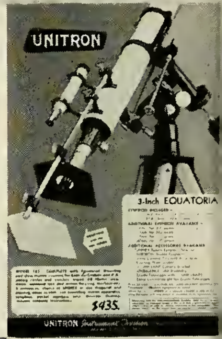
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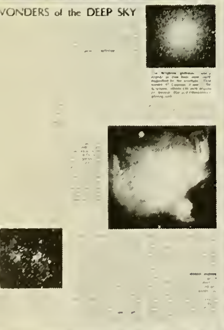
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SKY REPORTER

This month ushers in a period when all five of the naked eye planets will be visible

By Henry M. Neely

Sky watchers who find their greatest interest in following the planets will, this month, begin a schedule which has not been matched in many years. From now on until the end of August, there will be some nights of every month when all five of the naked eye planets will be visible.

This will be a particularly exciting experience for owners of small telescopes, for even moderate instruments will show the phases of Venus, the ice cap and some of the features of Mars, and the four largest of Jupiter's twelve satellites. Better instruments will reveal the mysterious colored belts of Jupiter, the great red spot and other features. Saturn's marvelous rings and five of its nine satellites also offer an interesting challenge.

Mercury, which is usually hard to spot, is less of a problem in March. With luck, observers should capture the elusive planet after sunset, from March 5 until March 16 or 17, particularly if binoculars are used and there is an unobstructed western horizon. Northern observers will fare better than southerners.

The star plans, *right*, show Mercury and Venus at four intervals in the month with the positions for about 7:00 p.m., local time. It will be well to begin looking about 6:30 as the twilight deepens. The plan for March 10 shows how the crescent moon can help locate these planets from March 10 to March 12.

Venus, of course, is always so brilliant that it cannot be mistaken for anything else. As an evening star over the west at this time, it shows a phase like the gibbous moon. The observer with a telescope should use a filter of some kind to cut down its glare.

Mercury will again be in position for observation, this time a "morning star," from mid-April to mid-May. It will be an "evening star" again in the first week of July. It will be fairly good in the dawn the last week of August and once again an evening object the first week of November.

Venus will continue to be higher and brighter for some months and, in the evenings, will be at its best position from mid-June to mid-August. Then we will lose it until it reappears in the dawn sky from mid-September until year's end.

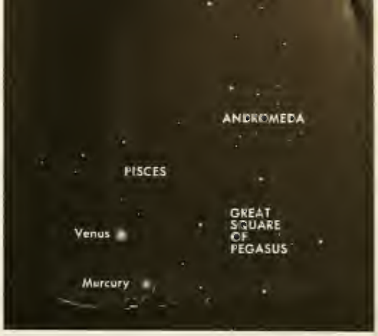
Mars is still a bright object in the night sky and is shown on this month's "roll around" map. It will gradually decrease in brightness until we lose it in early September.

Jupiter and Saturn are neighbors in the sky. The star plan on the next page shows them among the background stars, in their best positions near the meridian this month. Approximate times for this position are 5:00 to 5:30 a.m., during the first ten days; between 4:15 and 5:00 from March 10 to 20; and between 3:30 and 4:15 from March 20 until the end of the month is reached.

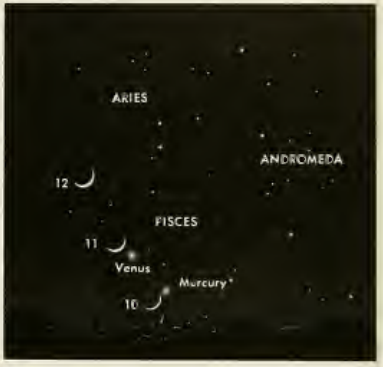
Jupiter rises in the southeast some four hours before these times, while Saturn follows, about two hours and forty minutes later than Jupiter.

Uranus is a sixth planet owners of telescopes can add to their observing schedule. On this month's map, find the constellation of Cancer and the cluster Praesepe. The fourth magnitude star below and to the left of Praesepe, where the dashed lines branch off, is Delta.

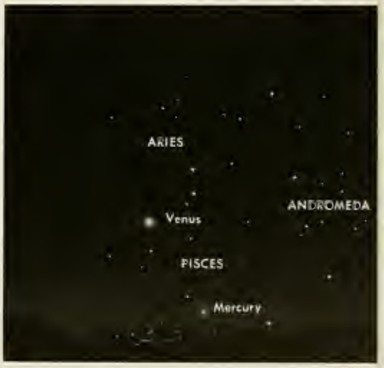
With a watch ready for timing, set Delta in the center of the field of view, note the time, lower the telescope only two-thirds of a degree and leave it there. In nineteen and a half minutes, Uranus will drift into the center of the field. This distant planet will not show a disk in instruments smaller than nine-inch diameter but good color vision will detect a greenish tint. It is of only sixth magnitude but no star so bright as that will be in the field at the time.



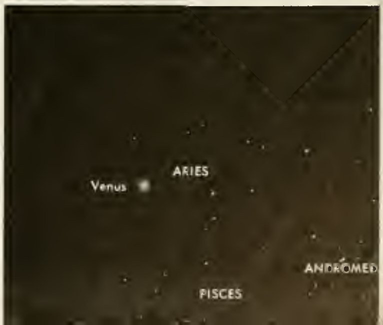
Venus and Mercury will appear thus in the west at 7:00 p.m. on March 5.



Waxing moon helps locate planetary pair at the same hour on these days.



Positions for March 20, *above*, and month's end, *below*. Mercury has set.



MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this monthly feature for NATURAL HISTORY.

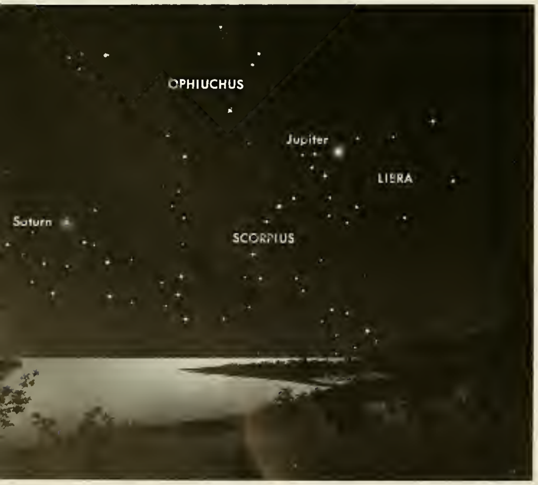
BELOW, in calendar form, are the principal astronomical events of interest this month:

MARCH 1 to 10: The moon enters the area of the JUPITER-SATURN star plan, *below*, from March 1 to 4. It will be above JUPITER on March 1. On March 2, it will be in OPHIUCHUS and above the star ANTARES. SATURN will be below the moon and to the left on March 3. On March 4, the moon will have passed over SATURN, to a position on the left of the planet.

MARCH 10 to 20: There is a chance of seeing an interesting, although not spectacular, meteor shower between March 10 and 12. These "shooting stars" are known as the ZETA BOOTIDS and seem to radiate from near the star just below brilliant ARCTURUS, shown on this month's map with "east horizon" at bottom. They are likely to be at their best about 3:00 A.M. when BOOTES is crossing the meridian. The moon and MARS make a striking picture, close together on March 16 and 17. Turn the "roll-around" map to bring "west horizon" to the bottom. On March 18, JUPITER ends its normal, eastward motion among the stars and begins its "retrograde" loop.

MARCH 20 to 31: At 3:55 A.M. (EST), on March 21, the sun reaches the vernal equinox. SPRING officially begins in the northern hemisphere, while AUTUMN begins for lands below the equator.

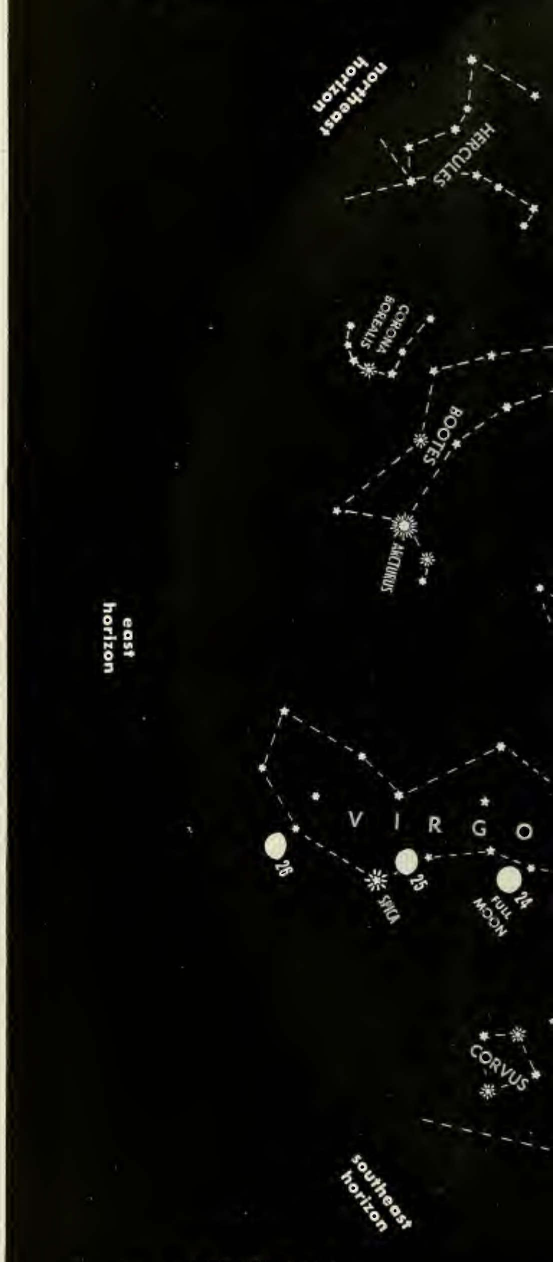
On certain nights, the moon gives a sure starting point for sky exploration. Find the moon for the date, and roll the map to bring that moon vertically above the horizon. The stars near the moon can now be identified without trouble or uncertainty.



SATURN AND JUPITER, this month, are seen together amid the constellations of the predawn sky, low over the south.

THE MOON'S PHASES

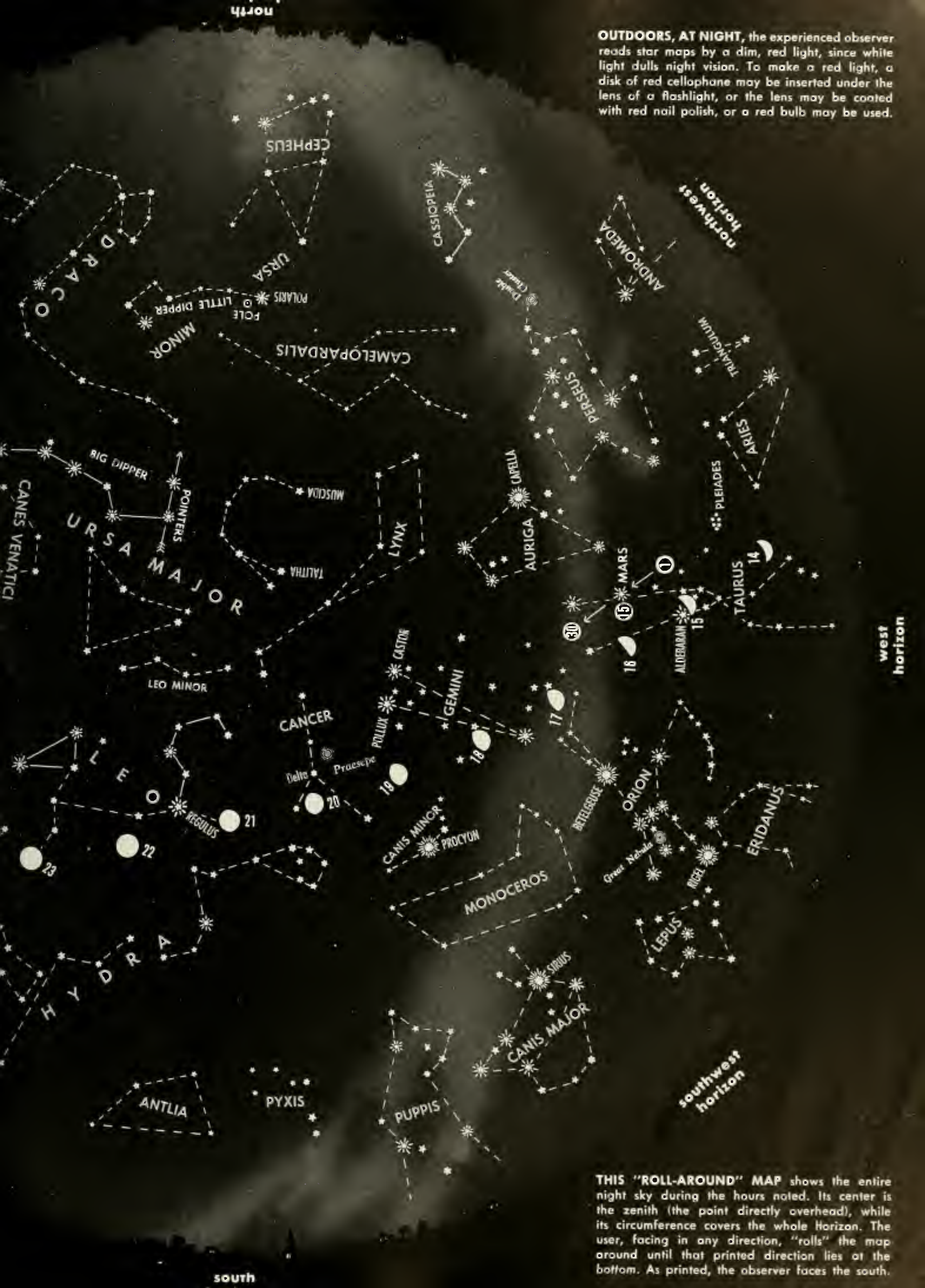
Last Quarter	March 1
New Moon	March 9
First Quarter	March 17
Full Moon	March 24
Last Quarter	March 31



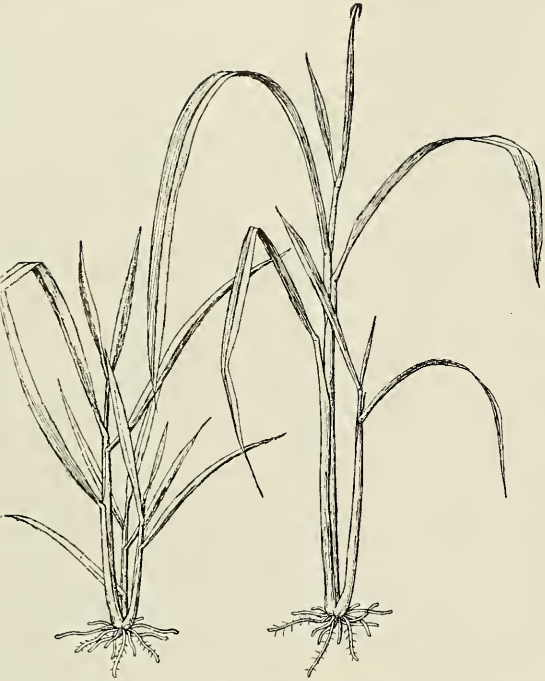
MARCH TIMETABLE

First week	10:00 to 11:00 P.M.
Second week	9:35 to 10:35 P.M.
Third week	9:05 to 10:05 P.M.
Fourth week	8:40 to 9:40 P.M.
Last week	8:10 to 9:10 P.M.

OUTDOORS, AT NIGHT, the experienced observer reads star maps by a dim, red light, since white light dulls night vision. To make a red light, a disk of red cellophane may be inserted under the lens of a flashlight, or the lens may be coated with red nail polish, or a red bulb may be used.


north
CEPHEUS
DRACO
URSA MINOR
LITTLE DIPPER
POLE
POLARIS
CASSIOPEIA
Double Cluster
ANDROMEDA
northwest horizon
TRIANGULUM
CAMELOPARDALIS
PERSEUS
ARIES
BIG DIPPER
POINTERS
CANES VENATICI
URSA MAJOR
MUSCIDA
TALITHA
LYNX
CAPELLA
AURIGA
PLEIADES
MARS
1
14
TAURUS
30
15
ALDEBARAN
15
16
west horizon
LEO MINOR
CASTOR
GEMINI
CANCER
POLLUX
17
18
Praesepe
Delta
19
20
LEO
REGULUS
21
22
23
CANIS MINOR
PROCYON
BETELGEUSE
ORION
ERIDANUS
Great Nebula
RIGEL
MONOCEROS
LEPUS
HYDRA
SIRIUS
CANIS MAJOR
southwest horizon
ANTLIA
PYXIS
PUPPIS
south

THIS "ROLL-AROUND" MAP shows the entire night sky during the hours noted. Its center is the zenith (the point directly overhead), while its circumference covers the whole Horizon. The user, facing in any direction, "rolls" the map around until that printed direction lies at the bottom. As printed, the observer faces the south.



Healthy and diseased rice plants show how ***bakanae-byu*** **("foolish seedling disease") increases sick plant's height.**

CHEMISTRY OF GROWTH IN PLANTS

Plants, like animals, produce hormones vital to their growth. Such a substance is gibberellin

By Anton Lang

PLANTS have two different "mechanisms" of growth. For one, they produce *new* cells—usually at the utmost tips of shoots and roots (and in a few other so-called "meristematic" regions). For the second, these new cells undergo a considerable increase in size, particularly in length—a process which takes place somewhat back of the tip of shoot or root. Botanists speak of these two processes as *cell division* and *cell elongation.*

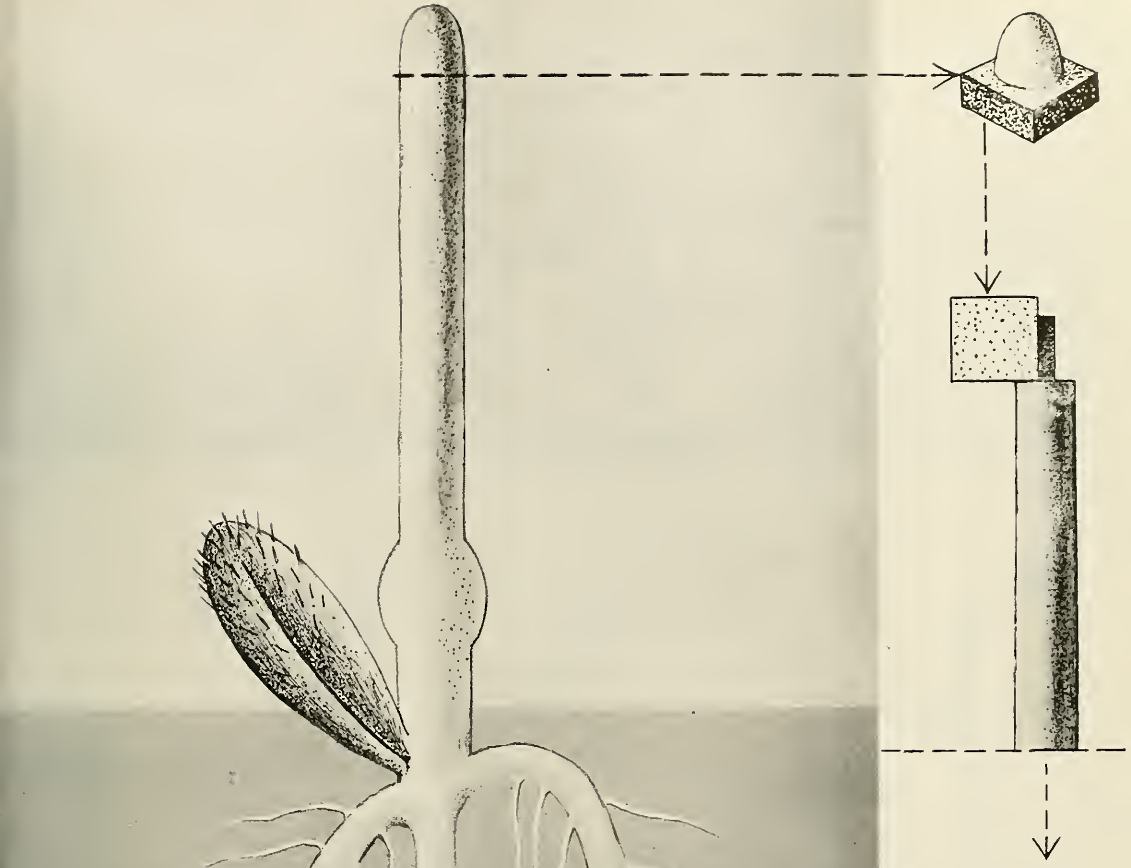
In the last few years we have witnessed what later, in all probability, will be considered a milestone on the road to understanding plant growth, and, particularly, its regulation by hormone-like chemical compounds.

The first plant-growth substance to be discovered was "auxin." Its existence was proven some thirty years ago by Frits Went—who may truly be called the "father" of plant-hormone science—by a very ingenious series of experiments with oat seedlings.

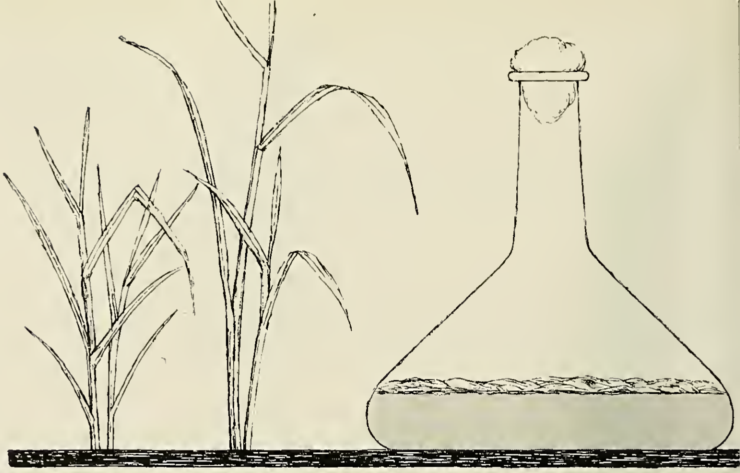
Went removed the tip of the first, sheathlike leaf (the "coleoptile") of a dark-grown oat seedling and placed it on a small block of agar jelly. After two or three hours, the tip was discarded and the agar block then placed on one side of the cut surface of the stump of another seedling whose coleoptile tip had been previously removed. The seedling then curved "away" from the block, showing that the flank beneath the block was making growth, while the opposite flank was growing less or not at all. A block of plain agar—that is, one on which no coleoptile tip had been sitting—caused no such effect. Thus, this experiment proved that the coleoptile tip produces a substance which makes the lower part of the coleoptile grow and which can be trapped in agar and then released from the agar back into the living plant.

Went's was not a mere discovery: it was a turning point in our entire outlook on plant growth. Before Went's evidence was presented, many botanists felt that hormones occurred only in animals and did not exist in plants. Hormones are organic materials which do not serve as nutrients but perform some regulatory function (such as regulation of heartbeat in man and animals, of metamorphosis in insects or of growth in plants) and which—the crucial point—*are made in one part* of the organism, animal or plant, and *function in another*, so that they have to be moved within the body from the place of their origin to that of their function. Even after Went's discovery, some scientists were reluctant to abandon the position that plants were hormoneless and, for some time, attempted to find other explanations for Went's observations.

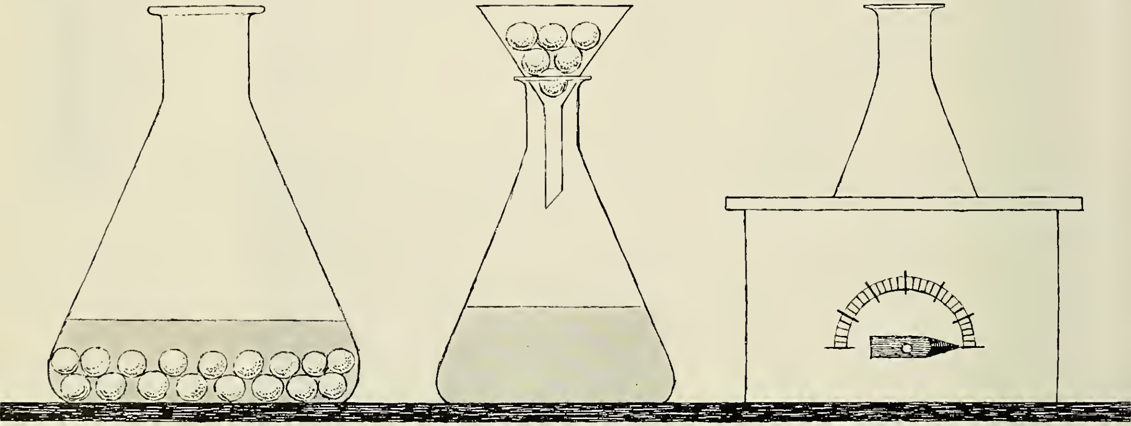
WENT'S evidence, however, was conclusive, and auxin soon became generally recognized as the first known plant hormone. Indeed, auxin came to be regarded as *the* plant hormone. Such primacy was quite understandable when one considers the great variety of functions in the plant that auxin has been proven to perform. It regulates the growth of plants, by both cell division and cell enlargement in length and thickness; it prevents the growth of lateral buds as long as the main or terminal bud of a shoot is active; it causes formation of roots in cuttings; it determines fruit growth and regulates the shedding (or abscission) of leaves, flowers and fruits.



Crucial experiment to demonstrate existence of auxin was performed by Frits Went thirty years ago. Went removed tip of coleoptile of oat seedling grown in water and placed it on a block of agar jelly. Then, discarding tip and cutting off tip of another seedling, he laid agar block on portion of this second seedling's stump. Seedling grew *away* from agar block, indicating growth took place on side of stump that was under the block. But agar block on which tip had *not* been placed caused no such effect. Went's conclusion: coleoptile tip had produced hormone that made plant grow.



Japanese experiment, at *right*, which was performed about thirty years ago but not immediately known by Western scientists, isolated the first gibberellin from fungus causing "foolish seedling disease." Fungus was grown in nutrient liquid and the resultant mold filtered off. When nutrient was then applied to rice seedlings which mold had never invaded, they showed tall growth that typified disease—despite absence of the fungus. Thus, substance distinct from mold—although produced by it—was proved to cause plant's growth spurt.

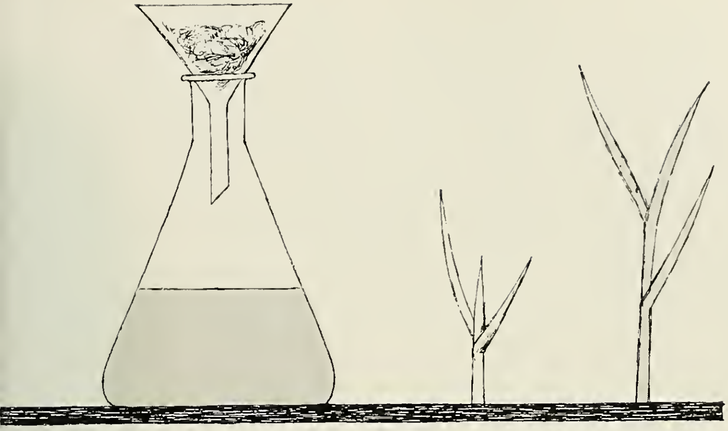


Went's discovery of auxin also resulted in a number of important measures in horticultural practice—for example, for rooting of cuttings, prevention of fruit-drop in apples, etc., and in weed control. It is, therefore, not surprising that, when botanists and horticulturists spoke of plant hormones (or plant-growth substances), they were thinking of auxin (and synthetic chemicals with similar actions) and of little else. Yet, Went himself had been the first to stress that not *all* phenomena of plant growth could be accounted for by auxin alone and that the discovery of auxin made the existence of other plant-growth hormones probable. In the last two or three years, this has become an established fact by the recognition of two new groups of plant-growth substances.

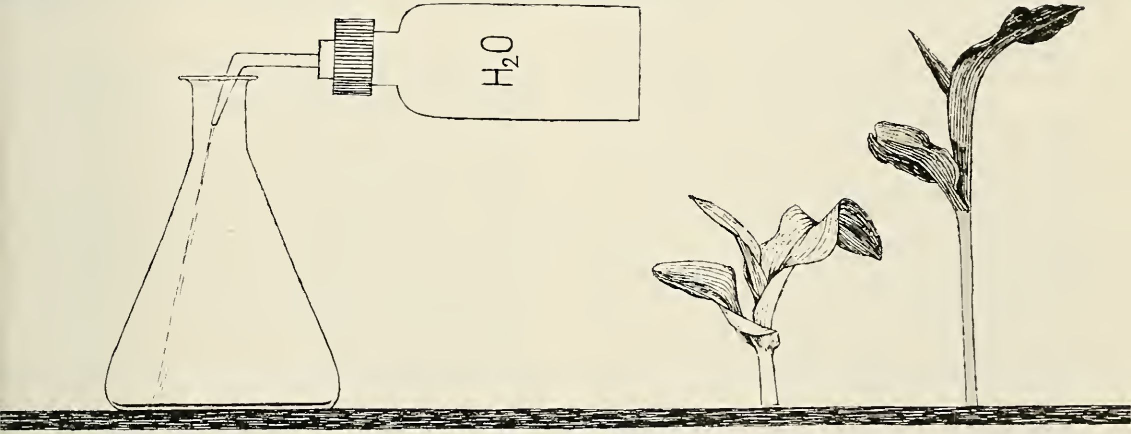
One such substance, "kinetin," was recently discovered by Folke Skoog, F. M. Strong, C. O. Miller and co-workers—a group of botanists and chemists at the University of Wisconsin. Among the properties of kinetin is the ability, in conjunction with auxin, to promote cell division in plant tissues and to cause the formation of buds and roots. The Wisconsin investigators have grown entire new plants from pieces of tissue taken from the central part (the pith) of the stem of the tobacco plant, placed in a test tube in the presence of appropriate quantities of kinetin and auxin. Kinetin has also been proven to have certain effects on seed germination and on the protein metabolism in leaves.

A group of growth substances isolated from the "milk" of the coconut (which have been studied by a number of botanists—particularly by F. C. Steward and co-workers at Cornell University) are, in all probability, related to kinetin, at least so far as their effects on plant growth are concerned. Yet these coconut milk substances seem to be quite different chemically: the name "kinins" has, therefore, been suggested for this combined group.

The second "new" group of plant-growth substances is not really new at all: the work that initiated their discovery, in fact, somewhat antedates the thirty-year-old discovery of auxin. But as this work was first reported



ENGLISH EXPERIMENTS, *below*, as well as some studies by scientists in the U.S. and in Italy, demonstrated that plants normally have gibberellins or at least gibberellin-like substances. Materials isolated from immature plant parts and purified, when applied to test plants, caused same tall growth as did fungus-derived gibberellins (*l.* to *r.*). But the gibberellins from these higher plants seem thus far (except for single type present in bean seeds) merely similar to—but not identical with—the four types already known from the fungus.



in the Japanese literature—a language that is foreign to scientists in both America and Europe—and as its general significance was less obvious, the work on this second group of substances—the so-called "gibberellins"—failed for many years to receive the wide attention that the studies of auxin and kinetin received from the very start. Let us trace the history of this discovery.

In the nineteenth century, a rice disease was described in Japan (and later in various other countries), which was given the name *bakanae-byu*, meaning "foolish seedling disease." The name comes from the fact that the diseased plants grow markedly taller than healthy ones, although they are otherwise weaker in development and remain more or less sterile. The disease was traced to a fungus that was named *Gibberella fujikuroi*, and which is the sexual stage of the species *Fusarium moniliforme*.

Many molds occur in two different forms, one having sex organs (the sexual or "perfect" stage) and one lacking them (the asexual or "imperfect" stage). In many cases, these two forms have first been described as separate organisms and have been given different names. Thus, sexual stages of *Fusarium* have been described under the name of *Gibberella*, and either name may be used to designate the mold. However, gibberellin is produced only by the *Fusarium* and not by the *Gibberella* stage of this mold. The word *Gibberella*, in Latin, means "little she-hunchback" (referring to the shape of the microscopic reproductive structures of the mold), but as we shall see, gibberellin makes plants grow bigger, so that the name gibberellin is somewhat of a double misnomer.

The Fusaria are soil-borne parasitic molds, known all over the world. They attack a great variety of plants, although each individual strain of the fungus usually attacks only one or a few plant species. The *bakanae* effect is produced only by some strains of *Fusarium*, which attack rice and a few other cereals, such as maize.

About thirty years ago, the Japanese plant pathologist Kurosawa found that *bakanae* symptoms could be obtained even in the *absence* of the fungus. After growing

Fusarium in a suitable nutrient liquid, he filtered off the mold. The nutrient, free of the mold, was then applied to rice seedlings, and these seedlings, which had never been invaded by the mold itself, exhibited the overgrowth typical of the *bakanae* disease. Evidently, the mold produces some material and releases it into the nutrient or directly into the host plant, and this material, not the mold as such, causes the *bakanae* symptoms.

SOME fifteen years later, a group of Japanese scientists at the University of Tokyo, headed by T. Yabuta and T. Hayashi, succeeded in obtaining this material in pure form. They gave it the name "gibberellin A" (later "A_1"). While most Japanese plant pathologists terminated their studies in this field in the 1940's, work on the biochemistry and physiology of the gibberellins continued through the war years at Tokyo University and, to a more limited extent, at Kyoto and Nagoya Universities.

However, this work remained unnoticed outside of Japan. It was not until the early 1950's that scientists in England and the United States became interested in the gibberellins. By 1954, chemists in England reported the isolation of a new (and chemically different) gibberellin—which they named gibberellic acid. Almost simultaneously, workers in the U.S. Department of Agriculture reported the isolation of both gibberellin "A" and of a substance they called gibberellin "X" (the latter proving to be identical to the gibberellic acid of the British workers.)

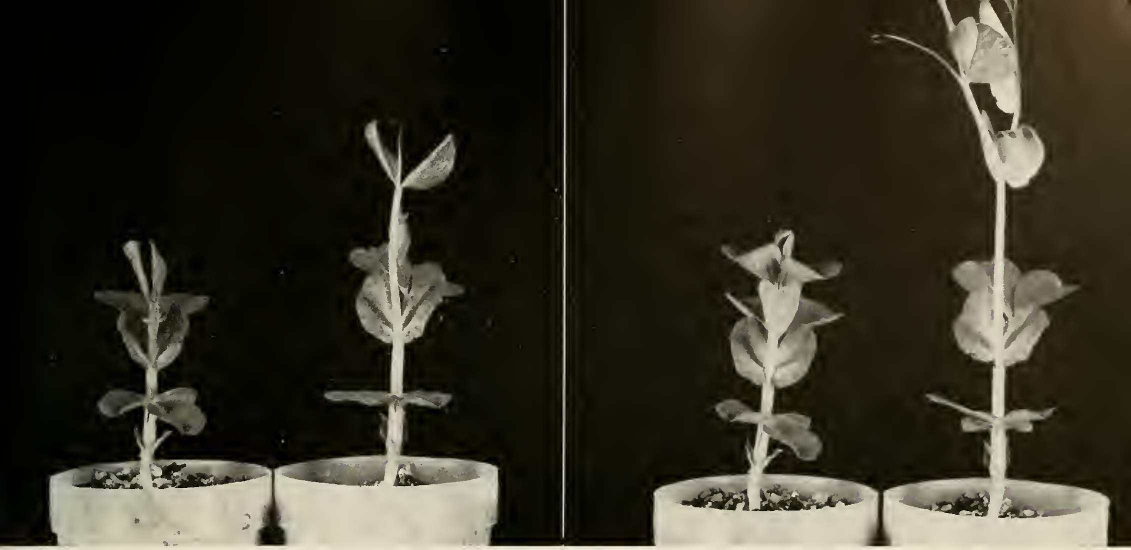
Somewhat later, the Japanese group reported the isolation of two more gibberellins. Thus, at the present time, four different gibberellins are known to be produced by the fungus: gibberellin A (gibberellin A_1, $C_{19}H_{24}O_6$), gibberellic acid (gibberellin A_3, gibberellin X, $C_{19}H_{22}O_6$), gibberellin A_2 ($C_{19}H_{26}O_6$) and gibberellin A_4 ($C_{18}H_{22}O_5$).

A tentative structure for gibberellic acid has been worked out by the British group. When compared with the structures of the best-known native auxin (3-indoleacetic acid), or of kinetin, it is evident that the three substances are quite unrelated in chemical terms. The basic structure of gibberellic acid is the compound called "fluorene," but the gibberellin molecule also appears to possess a lactone ring. This feature would make the gibberellins at least distant chemical relatives of still another group of substances, some unsaturated lactones (coumarin and some coumarin derivatives, such as scopoletin), which are believed to play a role in plant growth.

These unsaturated lactones seem to be *antigrowth* substances. In growing plant parts, they *reduce* the rate of growth and they are found, for example, in those regions of a root where the growth is becoming slower, about one-third of an inch back from the growing tip. It seems possible that these antigrowth substances determine *how long* a plant tissue is to grow.

Indeed, the growth of plants may be quite generally a matter of interplay between growth-*promoting* and growth-*inhibiting* chemical materials. Although the gibberellins clearly belong to the growth-promoting materials, their possession of a lactone ring may have some significance as yet not fully understood. It must be noted, however, that some chemists are not yet convinced that the gibberellins do possess the lactone configuration.

IF the growth-promoting effect of the gibberellins were limited to the rice plant, our interest in these substances would be modest. However, immediately after they had isolated gibberellin A, the Japanese scientists demonstrated that a number of different species of flowering plants—including maize, wheat, tobacco, tomato and the cucumber—would likewise respond to gibberellin by increasing their shoot growth. Today, a hundred or more plant species have been tested for their response to the gibberellins: all but two or three have been found to respond with an increase in their growth. In 1955, P. W. Brian, in England, reported that certain so-called "bush" varieties of peas and beans were more responsive to gibberellic acid treatment than their tall-growing, or "pole," counterparts. In 1956, it was reported by B. O. Phinney in the United States that certain dwarf mutants of maize, each of which is caused by the mutation of a single gene, would respond to minute amounts of gib-



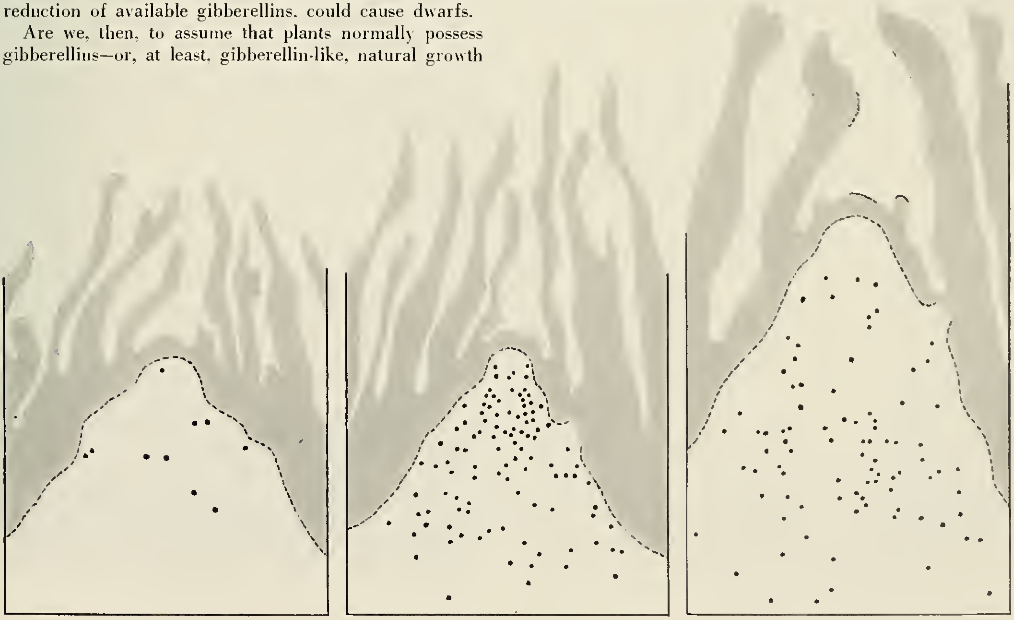
Growth-promoting effects of gibberellin are illustrated by experiment with pea plant. A comparison between treated and untreated plants of the Little Marvel variety—a dwarf form—shows difference in rate of growth. Photographs were taken over successive days at twenty-four-hour intervals.

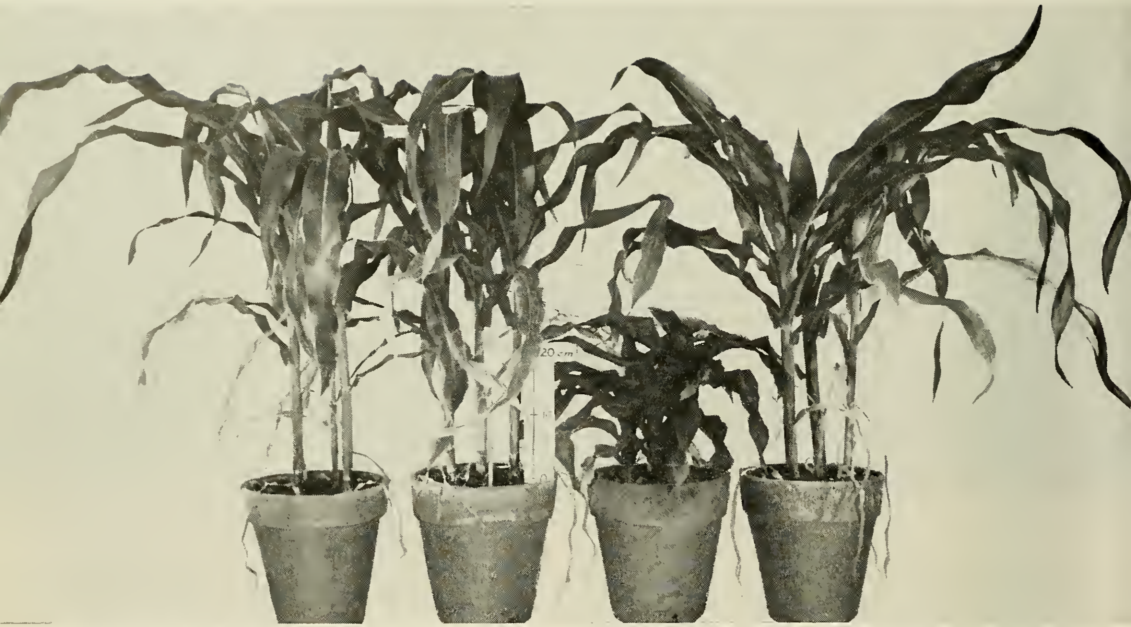
berellins by growing to normal size, while normal maize showed little or no response to an equivalent dosage.

Now, the known gibberellins have all been isolated from the one fungus, *Fusarium moniliforme*. If gibberellins occur naturally in flowering plants, an interesting interpretation of the phenomenon of dwarfism can be suggested. Evidence in the field of biochemical genetics strongly suggests that a single gene controls a single step in a particular metabolic pathway. Thus, it is quite possible that the dwarfing genes in maize (as well as in other plants) block specific steps in the production of natural gibberellins. Such a block, resulting in the absence or reduction of available gibberellins, could cause dwarfs.

Are we, then, to assume that plants normally possess gibberellins—or, at least, gibberellin-like, natural growth

Rosette plant, drawn in cross section, shows the effect of gibberellin dose on cell division (whose activity is indicated by dots) over day-long intervals. Gibberellin-induced cell-division activity may be so great that the stemless rosette plants prematurely form stems in process called "bolting."





Response of dwarf varieties to gibberellin is shown in this experiment with normal maize (two plants at left) and two dwarf mutants (at right). Treated and untreated normal forms look alike; treated dwarf form grew to normal height.

substances? This assumption has recently been shown to be a fact. B. O. Phinney and C. A. West in the United States, Margaret Radley in England and F. Lona in Italy have shown that immature seeds, leaves, stems, roots and flower buds of plants all contain materials that produce the same growth effects as do the fungus-derived gibberellins. And even more recently, British workers have shown that gibberellin A_1 is present in bean seeds—demonstrating that at least one of the four *Fusarium* gibberellins is, at the same time, a native product of higher plants. Except in this case, however, chemical studies indicate that the gibberellins isolated from higher plants, while probably similar to, are not identical with the gibberellins that are already known from the fungus.

In addition, these higher-plant substances differ chemically among themselves, depending on the plant source. Such results suggest that there may be a whole family of natural gibberellins in flowering plants. But the actual identity of these substances, and their relation to the known mold-made gibberellins, must await further work on the part of biochemists as well as plant physiologists.

Originally, it appeared that the action of gibberellin was concerned only with the second growth-mechanism of plants—cell elongation—leaving the number of cells unchanged. More recently, however, it has become evident that the gibberellins, in many cases at least, promote cell division as well as cell elongation. Their effect on cell division is very clear in the case of so-called "rosette" plants—plants which, in part of their life, have no elongate stem at all, the leaves seemingly coming directly from the upper end of the root.

Practical application of the gibberellins in agriculture is suggested by results of experiment with grapes. The grapes

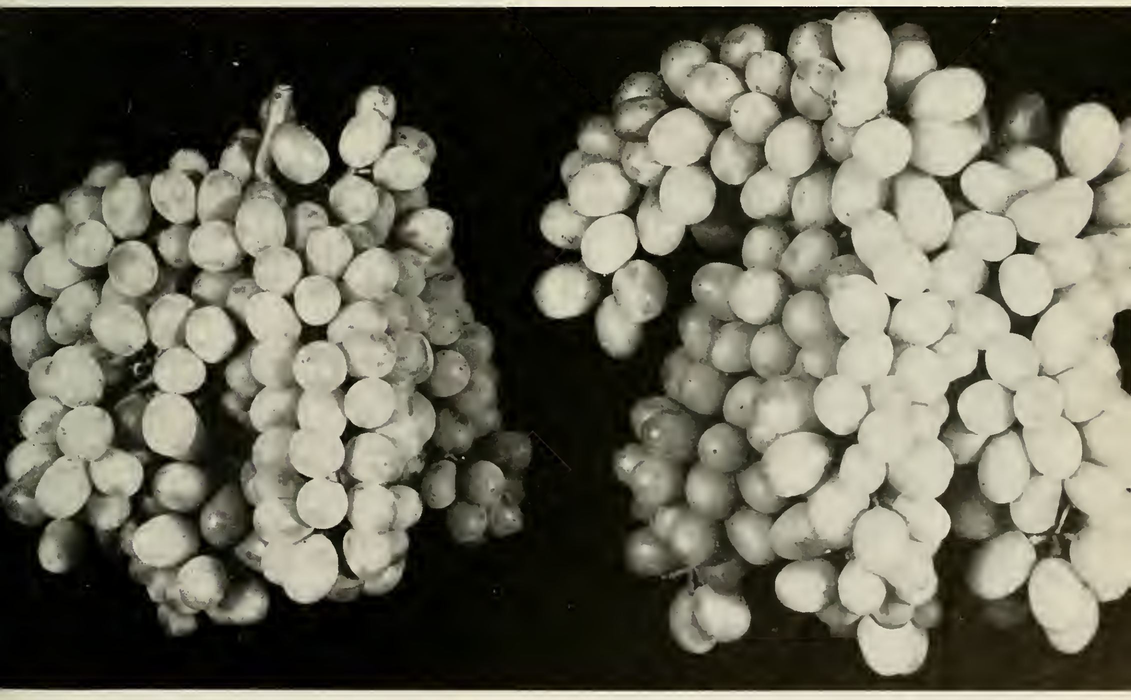
In these rosette plants, treatment with gibberellin results in the formation of a stem (a process sometimes called "bolting") and, as shown by R. M. Sachs and the author, this effect involves a spectacular boost in the plant's cell-division activity.

Rosette plants show another effect of gibberellin treatment (first demonstrated by the author and since confirmed by several other investigators). As long as they grow in rosette form, many of these plants do not produce flowers—the flowering depending on some special environmental condition, such as exposure to a period of low temperature. Thus, the foxglove flowers only after the plant has passed a winter in the open ground: if one were to raise foxglove in a moderately warm greenhouse, the plant would not flower at all. Foxglove is a so-called "biennial" plant. Other rosette species are "long-day" plants—that is, they flower only when the day's length exceeds a certain minimum. If the day's length is maintained below this minimum (for example, by covering the plants with a light-proof box or curtain each day at 5 P.M. and leaving them in total darkness until 8 A.M.), the plants may fail to flower at all. Many of our summer-blooming annuals, both ornamentals and wild species, belong to this class of long-day plants.

Now, gibberellin has been found to overcome both the cold requirement of foxglove and many other biennials, and the long-day requirement in many long-day plants—making the plants flower in conditions under which flowering ordinarily could not take place. Because the chemical promotion of flowering has been largely an unsolved problem of plant science, this effect is of great interest. Indeed, the gibberellins are the *first* chemical products to cause flowering under strictly nonflowering conditions in a large number of plants. Moreover, it has been found that the same effect can be achieved not only with the fungus-derived substances but also with the newly isolated gibberellins from higher plants. We have reason to feel, therefore, that gibberellins are true regulators of flowering in plants: that is, they occur *in* the plant itself and perform some essential function in switching the plant's growth from the production of leaves or the production of vegetative buds to the formation of flowers.

Our list of gibberellin actions is not exhausted with these effects on stem growth and flowering. Seeds of apples, peaches and some other fruit trees, for example, do not germinate unless they are "cold-stratified" or "after-ripened"—that is to say, subjected to the action of low temperature. If the embryo is removed from a nonstratified seed, it may germinate, but the resulting seedling will be a dwarf plant. Gibberellins have been shown to overcome this dwarfing in apple seedlings grown from nonstratified seeds.

If a potato were to be planted directly after harvest, it would fail to sprout for a period of several weeks to several months. It is in a state of "rest" or "dormancy," which is overcome only with time. Gibberellin has also



at left remain untreated; in the center, a solution of twenty milligrams to the liter has been applied; at the right, fifty mg/1. But agricultural research is only starting and most work is still confined to the laboratory or greenhouse stage.

Russian-born and German-trained, Dr. Lang came to the United States in 1950. This year, he has returned abroad to spend a sabbatical leave from UCLA, where he teaches, in Germany and Israel, continuing studies of plant growth.

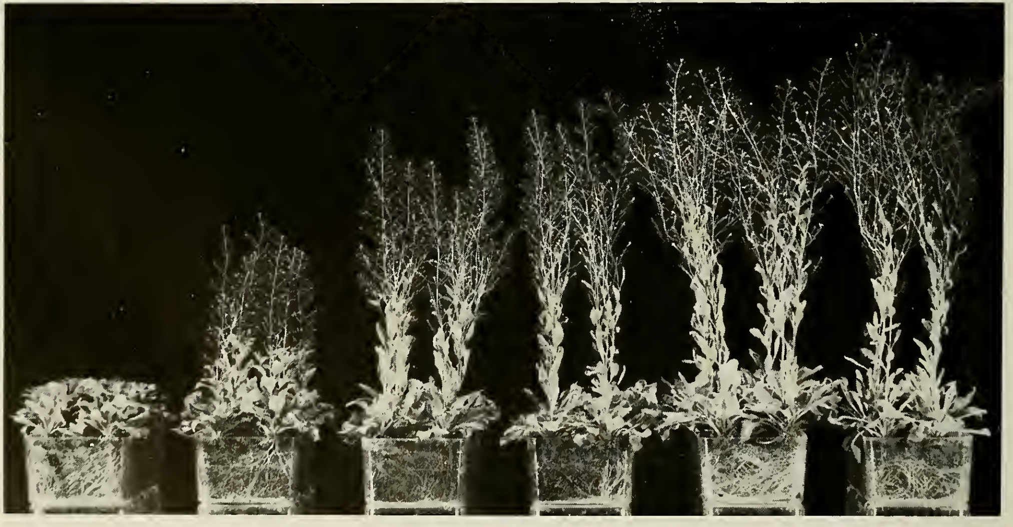
been found to break this resting condition, resulting in immediate growth. Moreover, the substance has been found to break the dormancy of tree buds in winter, to increase fruit set in tomatoes, and to promote germination in certain varieties of seed.

All these effects of gibberellin have attracted the attention of others besides the research botanist. Horticulturists, floriculturists and agriculturists are at work, and a great amount of study is in progress in hope of adapting gibberellin for the production of bigger and better crops. Some results are encouraging, but much more work is needed before we will be able to tell the extent to which the gibberellins' effects on laboratory- and greenhouse-grown plants can be translated into the more practical terms of commercial crop production.

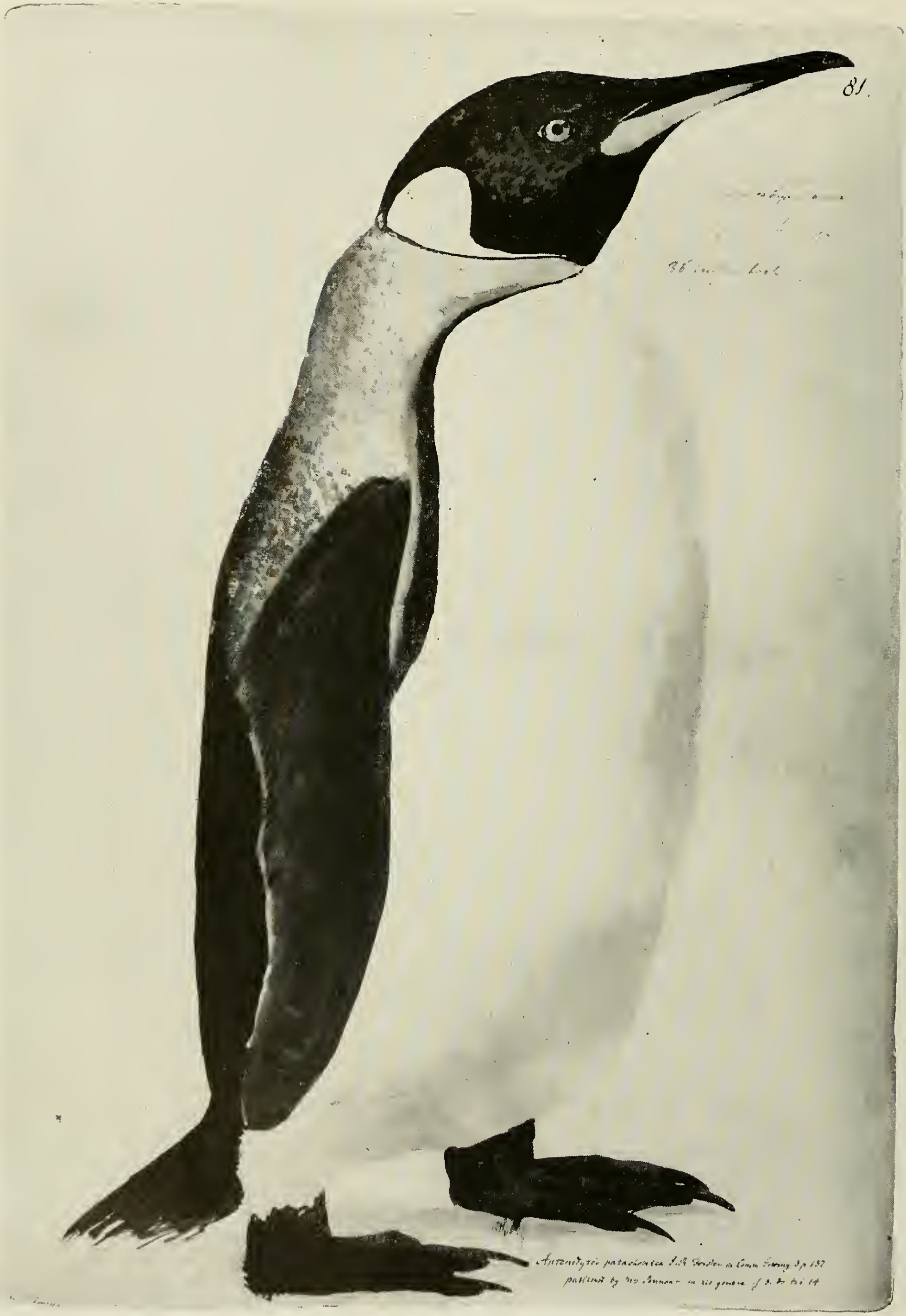
Yet, it is not too soon to say a few words regarding the impact of all this new knowledge about the plant-growth substances on our thinking about plant growth in general. We have pointed out that auxin and kinetin have not a single action, but a series of different actions, auxin regulating cell division and elongation, the growth of lateral buds and of fruits, and the abscission of leaves and other plant parts; kinetin affecting cell division, root and bud formation, seed germination, etc. The same is obviously true of the gibberellins. Furthermore, auxin, kinetin and gibberellin cannot replace each other. For example, neither gibberellin nor auxin alone will support cell division in a plant tissue such as tobacco pith—where cell division is dependent on the supply of kinetin. Nor will either auxin or kinetin—alone or in combination—cause bolting and flowering in a gibberellin-requiring rosette plant, such as the carrot.

Thus, the three major identified types of growth substances perform different functions, and all three seem to be required if a plant tissue is to grow at all. Finally, the ratio of the three seems to determine *how* it will grow. Skoog and Miller showed that if tobacco pith tissue is grown in the presence of relatively high quantities of auxin and low quantities of kinetin, it will form roots. If more kinetin is supplied, shoots are formed instead. In turn, a rosette plant seems to need auxin and relatively little gibberellin for vegetative growth, but more gibberellin for bolting and flowering.

This suggests that plants do not use one special chemical compound to regulate cell division, another to regulate stem elongation, and a third to determine root, bud, or flower formation; rather, all these processes are regulated by variations in the levels and ratios of the same compounds. A system of checks and balances appears to be in operation, by which plants achieve a great many separate effects using a limited number of materials—but using them all, or most of, the time. It is, of course, far too soon to say that all aspects of plant growth will necessarily be explained in terms of auxin, kinetin and gibberellin. This is, on the contrary, unlikely. We may well find that the growth-inhibiting unsaturated lactones are active members of the partnership, and we may discover still further groups of growth-promoting chemicals in plants. But in trying to understand the chemical regulation of plant growth, present research is suggestive of one conclusion. In the future, we may do well to look, not only for new, specific plant-growth substances, but also for subtle differences in quantity and ratio among the plant-growth substances we already know.



Regulation of flowering is still another of gibberellin's effects. Particular conditions of temperature and of light required for plants to blossom may be overcome by use of hormone—as in water pimpernel, *above*, brought to flower despite short days; and carrot, *opposite*, flowering after treatment (center) as after a normal season of cold (right).



First emperor penguin was sketched, *above*, by Forster, in 1775, on Cook's second voyage. He believed it to be a king.

PART II

HISTORY OF THE PENGUINS

Reduced today to six genera, these birds were once far more numerous

By Robert Cushman Murphy

PENGUINS, unlike cranes, falcons and other striking and widely distributed birds, carry no lore from antiquity. Confined to the Southern Hemisphere, they were unknown to European man until the Age of Exploration. It would have been possible for Portuguese mariners to sight penguins near the Cape of Good Hope in the year 1488, but the earliest certain record seems to be that of Pigafetta, historian of the first circumnavigation of the world: in 1520, Magellan's fleet encountered huge flocks of the "strange geese," as Pigafetta called them, on the coast of Patagonia.

Realization that the southern oceans were inhabited not merely by "the" penguin, but by numerous distinct *kinds* of penguins, came only slowly. Linnaeus, in 1758, wrote the first scientific diagnosis and bestowed the first technical name (*Spheniscus demersus*) upon the South African jackass penguin. Similar binomial designation of seventeen additional species has followed gradually during the intervening two centuries.

The kinds of penguins earliest described were, as might be expected, those occupying extensive ranges in the South Temperate Zone. Six of these, in addition to *demersus*, were made known by naturalists before the end of the eighteenth century. But discovery of the two truly antarctic species—as well as those of restricted range at out-of-the-way islands (and those that had been overlooked because of close resemblance to kinds already familiar)—came only in the nineteenth and twentieth centuries.

The emperor penguin, the most exclusively antarctic of all birds (NATURAL HISTORY, February, 1959), was named in 1844, after the south polar voyage of Sir James Clark Ross, and one naturalist wrote in 1868, "Thanks to the many descriptive documents furnished by ancient as well as modern navigators, the natural history of penguins may be considered complete." Yet the Galápagos penguin, which lives at the equator, remained unknown until 1871, the white-flippered penguin (of the Banks Peninsula, New Zealand), until 1874, and the royal penguin, of Macquarie Island, until 1876—while the technical name of one species, the Snares Islands penguin, dates only from 1953.

The eighteen species of penguins surviving in the world today are, so to speak, only the tail of an immensely long history. In 1859, the great Thomas Henry Huxley described the first-known extinct penguin—from fossil bones found in New Zealand deposits, and now attributed to the Early Miocene. Since then, a wide variety of other fossil forms has been discovered in New Zealand, South Australia, Patagonia and Seymour Island in West Antarctica. Thus, the known distribution of all extinct penguins is wholly included within the Southern Hemisphere range of living varieties. In recent years, two definitive studies of the fossil forms of penguins have been published: one by Simpson of The American Museum (1946) and another by Marples of the University of Otago, New Zealand (1952). Both authors show a conservative tendency toward reducing the number of named fossil penguins, the uniqueness of some of which had been based upon inadequate or doubtful skeletal remains. Even with these reductions, however, their researches indicate the existence of eighteen genera and about twenty-five species of fossil penguins. It is therefore evident that the Tertiary penguin fauna was far richer than the one that has survived to the present period.

Another fact emerging from recent fossil studies is the substantial antiquity of the penguins. Creatures that were typical penguins in all anatomical respects walked upright and swam with flipper-like wings as long ago as the Late Eocene, fifty or more million years behind us. The finding gives us another link in a long chain of objective testimony in support of the view that the birds, and especially marine birds, underwent their rapid and pronounced evolution at some period in the remote past. The rate of evolutionary change for the Class Aves since the early Tertiary has been vastly less than that shown in most orders and families of the higher mammals.

THE size range among extinct penguins was greater than is the case today. Species of two Miocene genera attained statures of five feet, or slightly more, and an estimated weight of between two and three hundred pounds. For comparison, today's emperor penguin—the largest species—stands under three-and-a-half feet tall and may weigh up to ninety pounds. Nor is the range in size the only difference between fossil and living forms. *All* fossil penguins differ from modern penguins to a greater extent than the latter do from one another. Furthermore, although all of the fossil penguins belong to the same family as all of the penguins living today, not one of the extinct forms can be regarded as structurally ancestral to any

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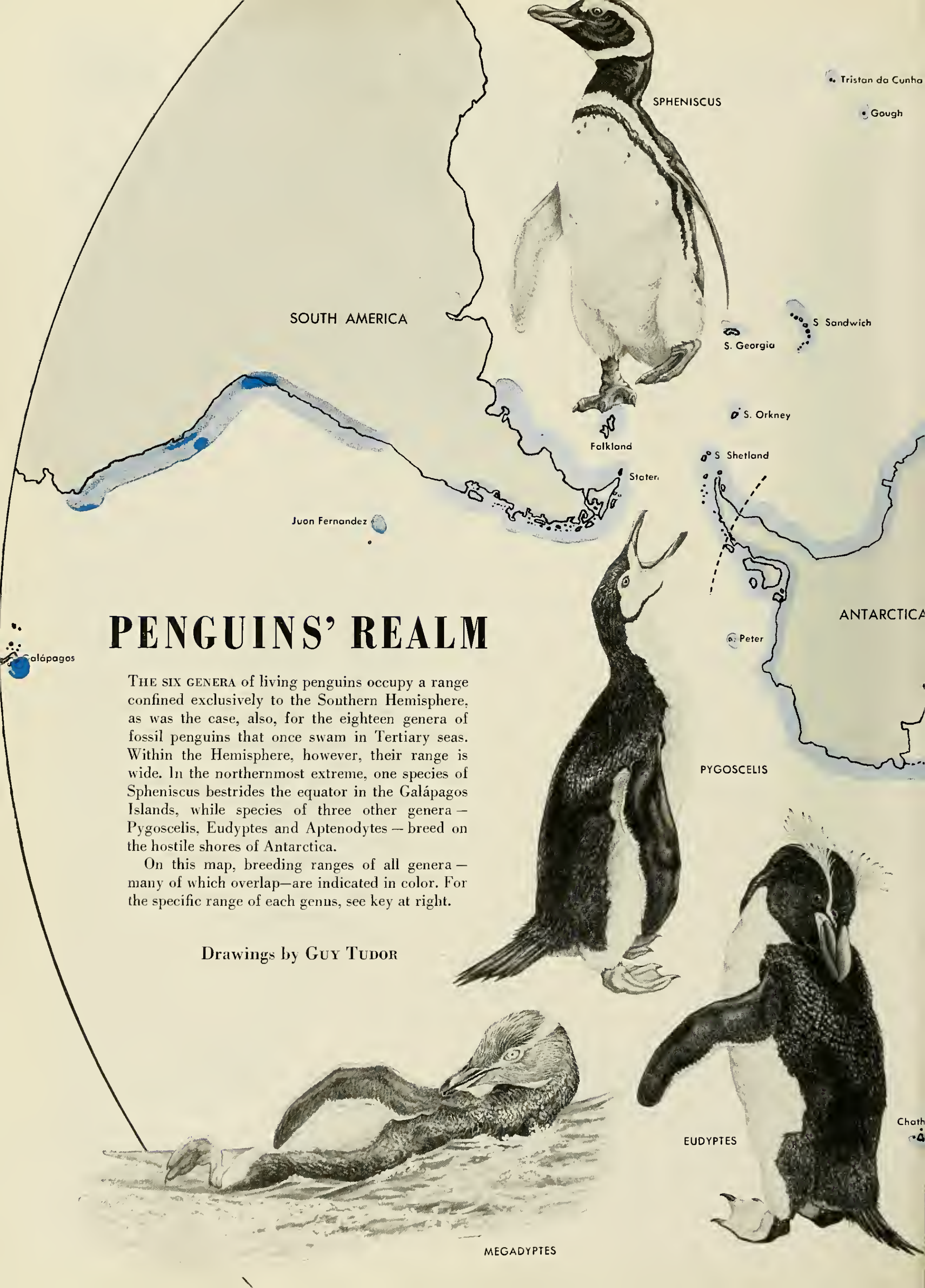
DR. MURPHY, Lamont Curator Emeritus of Birds at THE AMERICAN MUSEUM, is a recognized expert on penguins. His taxonomic review, here, completes a series begun in February with the account of the emperor's life cycle. MR. TUDOR has previously provided illustrations of the nine Tytonidae.

PENGUINS' REALM

THE SIX GENERA of living penguins occupy a range confined exclusively to the Southern Hemisphere, as was the case, also, for the eighteen genera of fossil penguins that once swam in Tertiary seas. Within the Hemisphere, however, their range is wide. In the northernmost extreme, one species of Spheniscus bestrides the equator in the Galápagos Islands, while species of three other genera — Pygoscelis, Eudyptes and Aptenodytes — breed on the hostile shores of Antarctica.

On this map, breeding ranges of all genera — many of which overlap—are indicated in color. For the specific range of each genus, see key at right.

Drawings by GUY TUDOR


Tristan da Cunha
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SPHENISCUS
SOUTH AMERICA
S Sandwich
S. Georgia
S. Orkney
Falkland
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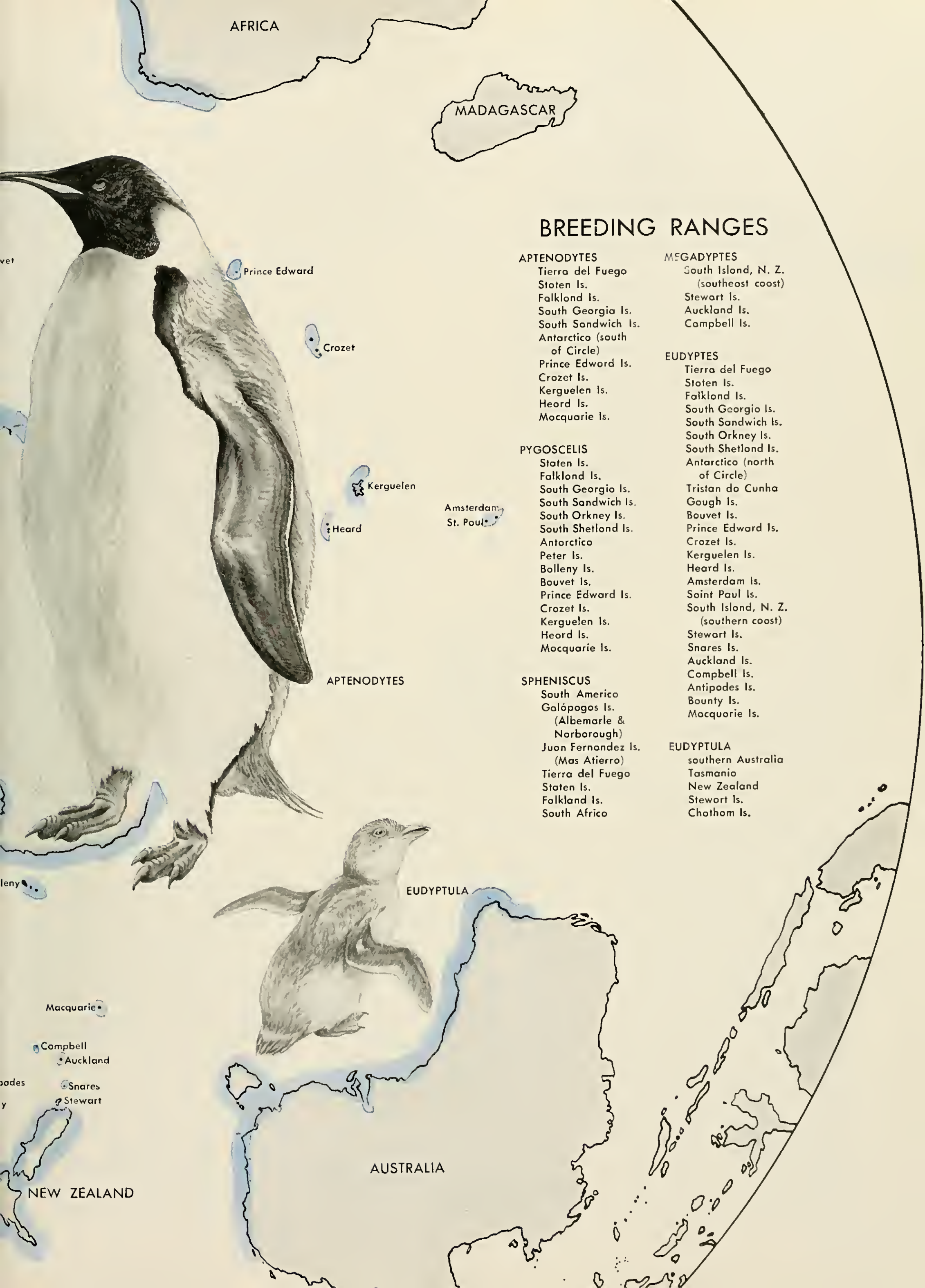
PYGOSCELIS
EUDYPTES
Chath
MEGADYPTES


AFRICA
MADAGASCAR
vet
Prince Edward
Crozet
Kerguelen
Amsterdam
St. Paul
Heard
APTENODYTES
leny
EUDYPTULA
Macquarie
Campbell
Auckland
podes
Snares
y
Stewart
AUSTRALIA
NEW ZEALAND

BREEDING RANGES

APTENODYTES
- Tierra del Fuego
- Staten Is.
- Falkland Is.
- South Georgia Is.
- South Sandwich Is.
- Antarctica (south of Circle)
- Prince Edward Is.
- Crozet Is.
- Kerguelen Is.
- Heard Is.
- Macquarie Is.

PYGOSCELIS
- Staten Is.
- Falkland Is.
- South Georgia Is.
- South Sandwich Is.
- South Orkney Is.
- South Shetland Is.
- Antarctica
- Peter Is.
- Balleny Is.
- Bouvet Is.
- Prince Edward Is.
- Crozet Is.
- Kerguelen Is.
- Heard Is.
- Macquarie Is.

SPHENISCUS
- South America
- Galápagos Is. (Albemarle & Norborough)
- Juan Fernandez Is. (Mas Atierra)
- Tierra del Fuego
- Staten Is.
- Falkland Is.
- South Africa

MEGADYPTES
- South Island, N. Z. (southeast coast)
- Stewart Is.
- Auckland Is.
- Campbell Is.

EUDYPTES
- Tierra del Fuego
- Staten Is.
- Falkland Is.
- South Georgia Is.
- South Sandwich Is.
- South Orkney Is.
- South Shetland Is.
- Antarctica (north of Circle)
- Tristan da Cunha
- Gough Is.
- Bouvet Is.
- Prince Edward Is.
- Crozet Is.
- Kerguelen Is.
- Heard Is.
- Amsterdam Is.
- Saint Paul Is.
- South Island, N. Z. (southern coast)
- Stewart Is.
- Snares Is.
- Auckland Is.
- Campbell Is.
- Antipodes Is.
- Bounty Is.
- Macquarie Is.

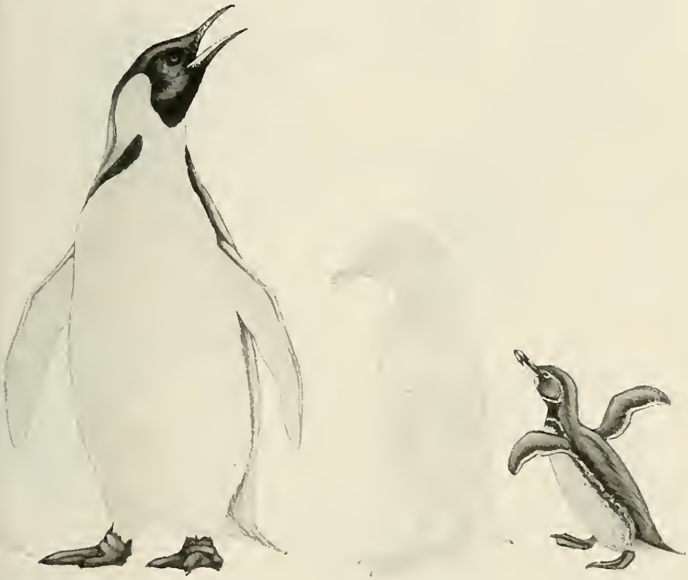
EUDYPTULA
- southern Australia
- Tasmania
- New Zealand
- Stewart Is.
- Chatham Is.

particular modern species. Indeed, we know neither more nor less about the progenitors of present-day penguins than we do about those of the whole family and order: as to their immediate ancestors in the Paleocene, or earlier, we have no clues. The gaps in the paleontological record allow the penguins to burst upon us without antecedents—fully adapted for their unique manner of life. To date, we can only postulate from morphological evidence (and from certain traits of behavior and life history) some remote affinity with the petrels and albatrosses, and perhaps with the pelicans and their allies. But the evidence as to when the basal branches of these birds diverged still remains hidden in the fossil deposits.

Concerning the probable steps in penguin evolution, Simpson's hypothesis offers a persuasive picture. This is that primitively flying birds became oceanic in habitat, adopted submarine swimming as well as aerial flight in the food quest, and then abandoned flight for exclusively submarine locomotion. The penguins' efficient and peculiar pedestrian adaptation, ashore, was concomitant with the change from air to water: instead of flying from feeding to breeding grounds, the penguins had to walk to them. Part of the appeal of this interpretation is owing to phases of the same pattern to be seen in other groups of marine birds. Among the auks, for example, one (the great auk) became flightless, presumably within recent geologic time. The same is true of one species of cormorant (the Galápagos cormorant). In the family of diving petrels (Pelecanoididae), molt of the wing quills periodically reduces the birds to a flightless stage, during which they can still "fly" and feed under water in the manner of penguins. There must have been a point, not reached by these birds but reached by the ancestors of penguins, Simpson postulates, when the advantage of "flying" underwater outweighed that of flying in air, assuming that the appropriate genetic variation made its appearance.

Since the several recognized subfamilies of fossil penguins all vanished without leaving any direct descendants, we now have for consideration only our own contemporaries —of the subfamily Spheniscinae, family Spheniscidae, order Sphenisci-

FIGURE OF MAN, *left*, provides scale (6′) for this assemblage of fossil and living penguins. From left, they are: the largest of the Miocene species, *Pachydyptes* and *Anthropornis* (estimated to weigh about 250 lbs. and stand about five feet in height); other "giant" Miocene species, such as *Palaeeudyptes antarcticus* (in which height-estimates range around four feet); the emperor of today (largest of the living penguins, over three feet in height); Miocene species of moderate size, such as *Palaeospheniscus patagonicus;* and, finally, one of the small, contemporary penguins, the Galápagos. Shapes of the fossils are imaginary *(after* Simpson).



formes. These are arranged in six genera (all the names of which are descriptive—and slightly absurd—renderings from the Greek), as follows:

Genus *Eudyptula* ("little true diver"): this genus includes two species, both of the Australia–New Zealand area; the blue (*minor*) and the white-flippered (*albosignata*), smallest members of the family.

Genus *Megadyptes* ("big diver"): this genus includes only one species; the yellow-eyed penguin (*antipodes*) of New Zealand, which is not "big" as penguins go.

Genus *Spheniscus* ("little wedge"): this genus includes four closely related and rather widely distributed species: *demersus*, popularly, the jackass (from the braying penguin voice, of course): *magellanicus*, the Magellanic; *humboldti*, the Peruvian: and *mendiculus*, the Galápagos penguin.

Genus *Aptenodytes* ("wingless diver"): this genus includes the two largest species: *patagonica*, the king; and *forsteri*, the emperor (the latter being the giant of modern penguins).

Genus *Eudyptes* ("true diver"): this genus includes six species of moderate-sized penguins with yellow crests, or pompons ("macaroni"), on their heads. The specific names of these six have been much confused and the popular names of several of them have been legion. Herein, I shall call *pachyrhynchus* the fiordland, after the fiords of its native New Zealand; *schlegeli* the royal; *crestatus* the rock-hopper; *robustus* the Snares; *chrysolophus* the macaroni; and, finally, *atratus* the erect-crested penguin. The members of this genus still need comprehensive taxonomic study. Several of them are closely related, and it is possible that one or more of the insular (and extremely local) so-called species will prove to be no more than geographic races.

Genus *Pygoscelis* ("rump-legged"): this genus embraces the last three species of penguins; *papua*, the gentoo; *antarctica*, the chin-strap; and *adeliae*, the Adélie penguin. *Pygoscelis* is not as compact a genus as each of the other five: the gentoo differs rather markedly from its two congeners.

Of these eighteen species of penguins, I have had the good fortune to see live examples of all but two. Six I have known only as captive birds. With the ten others, however, I have dwelt in their own wild homes for periods ranging from a few days to as long as five months.

WHAT are the criteria of classification for the penguins—or for any other organisms constituting an obviously natural assemblage? A taxonomist working with collected specimens of birds, for example, makes use of the plan and details of bodily structure, the color and pattern of the plumage and—insofar as field information is available—resemblances and differences in behavior. At the same time, he is aware that he is making value judgments without benefit of an actual evolutionary and embryological record, without knowing the nature of past genetic mutations or the host of ecological and physiological processes that enter into the making of what we regard as "species."

In dealing with several member species of a single genus, these problems appear simpler, although still by no means simple. But, in estimating relationships among genera, the missing evidence cuts down heavily on certainty. We can only make the most of what we have, and take heart from the truth that all scientific conclusions are tentative—destined to be modified or perhaps abandoned.

Let us consider plumage as a criterion among penguins. That brilliant naturalist, Dr. Edward Wilson, who died with Scott on the march from the South Pole, pointed out in 1907 that, in penguin plumage, nine-tenths of the distinguishing characteristics appear on the head and neck. Except for size, it would be difficult—if not impossible—to identify any among a dozen species of decapitated penguins. Because of the low silhouette of penguins floating in the water, their heads constitute a recognition area—the only part, it could be said, that is prominently exposed to the view of their fellows. This may be one explanation of why strong differences in bill color, in bold markings of head and throat and in bright superciliary plumes, ear-patches and similar ornamentation, have evolved among the penguins. The remainder of the penguin's body, even to the dark soles of the feet, which are turned upward while it is swimming, appear to be colored and countershaded chiefly according to the canons of low visibility under water.

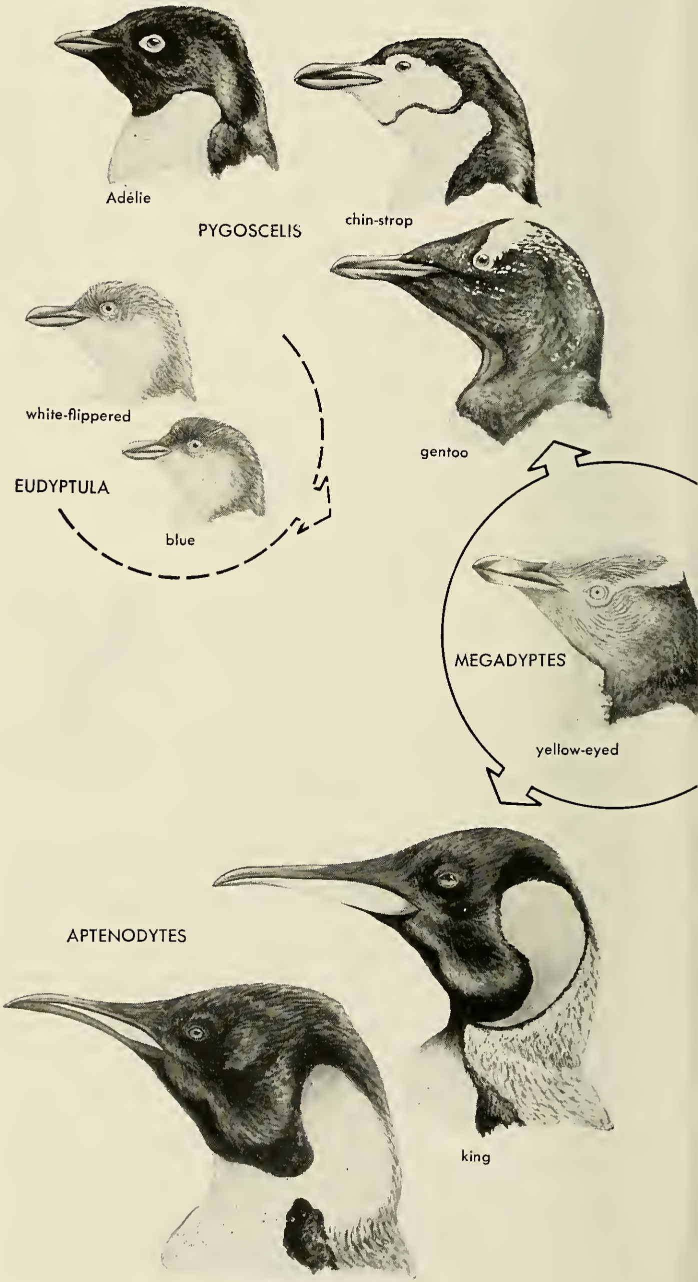
The most conspicuous distinguishing features exhibited by penguins center in the head, as we shall see. Their skeletal, muscular and visceral characteristics are notably uniform throughout the subfamily—which is the reason, indeed, that the six genera are regarded as comprising only a single subfamily, the Spheniscinae.

Now that we have brought the penguin problem to a head, so to speak, let us attempt to justify the assumed relationships set forth in our diagram at *right.*

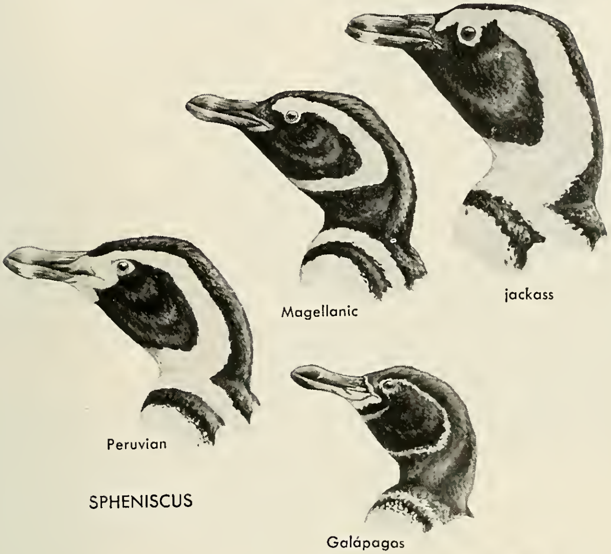
The genus *Eudyptula*, small in size and devoid of head decoration, has been widely favored as the most primitive of living penguins. In skeleton and plumage, it can certainly be considered the most "larval": the adult stage of *Eudyptula* rather closely resembles the youthful stages of penguins belonging to several other genera. To that extent, this genus is a reasonable "structurally ancestral" choice, although its plainness offers no proof whatsoever of its evolutionary history. Both species of *Eudyptula* have gray eyes. Both nest in dim niches or shallow burrows, laying two eggs. This is the usual complement of eggs among most penguins, except the single-egg genus, *Aptenodytes*. The gentoo, however, commonly lays three eggs, of which one is always infertile; the rockhopper often lays three; the royal, only one. One of the two *Eudyptula*—the white-flippered penguin—has a uniquely limited range: it is known to nest only on the shores of the small Banks Peninsula, on the eastern coast of New Zealand's South Island.

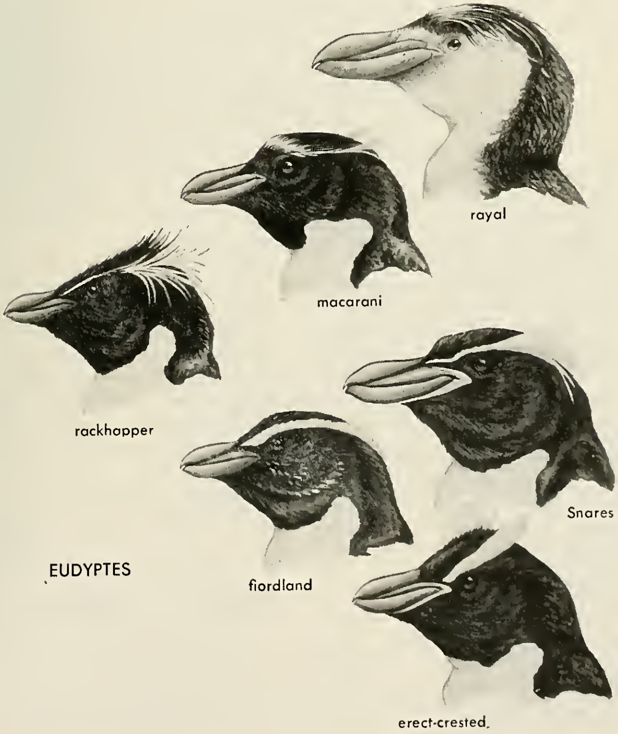
Our diagrammatic arrow leads from *Eudyptula* to *Megadyptes* with good reason. *Megadyptes*, the only penguin with a yellow iris, is the *most* generalized of the five groups that possess

THE EIGHTEEN SPECIES



OF MODERN PENGUINS

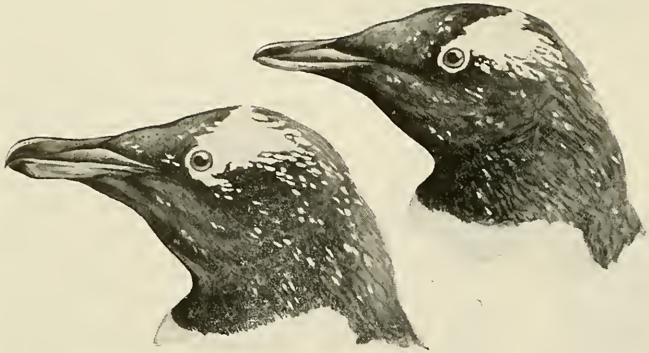




more or less elaborately decorated heads and necks, eyes of various colors, and pronounced differences in the build, as well as the color, of the beak. We might say that, among the four remaining genera of penguins, *Megadyptes* represents a sort of "average." The shape and position of its diadem resemble the white fillet on the head of the gentoo penguin (*Pygoscelis*); the color of this mark foreshadows the yellow or golden plumes of all the species of *Eudyptes*; the green gloss on its crown, due to tiny specks of orange pigment, approaches the same condition on the head of the king penguin (*Aptenodytes*). The bill of *Megadyptes* tends in shape toward the truncated bill found in the genus *Spheniscus*. Like all the species of the latter genus, *Megadyptes* also sometimes shows a speckling of black feathers in the white plumage of the breast. In its habit of nesting in depressions in the ground, sometimes under stumps, fallen trees and shrubbery, *Megadyptes* suggests the burrowing nesting pattern of both *Eudyptula* and *Spheniscus*.

The four species of *Spheniscus* offer a familiar and natural type of taxonomic and geographic sequence. All belong to the temperate climatic belt. Even though one of the species lives at the equator, in the Galápagos Archipelago, its environment is tempered by a cool ocean current. The particular distribution of the other three species along the continental coasts of South America and Africa is similarly current-controlled. The Galápagos species (the smallest—scarcely larger than the *Eudyptula* penguins) has a relatively obscure plumage pattern, a fact more likely to be degenerative than primitive. In other characters, it is closest to its nearest neighbor, the Peruvian penguin, even though the bars crossing its throat are double—as in the Magellanic penguin.

Contrary to popular opinion, few penguins are antarctic. The genus *Pygoscelis*, however, has three species that range progressively from areas of relatively moderate climate, such as the Falkland Islands, to the truly polar coasts. The gentoo, the chin-strap and the Adélie show a sequence of adaptive modifications that harmonize with their respective environments. In the Adélie, which nests in a region of severe blizzards, the nostrils are feather-screened in a way that would keep snow particles out of the respiratory



Penguin subspecies, *above,* serve as illustration of Allen's Rule. Typical gentoo. *left,* only populates northerly range. The other subspecies of gentoo, *right,* ranges far to polar south. Its bill. wings and feet are smaller in size.

tract. The chin-strap penguin. of intermediate distribution, has this character less pronounced, whereas the northerly gentoo lacks it altogether. The gentoo, however, is itself represented by geographic races associated with different climatic zones. Well to the south of the range of the northerly subspecies (*Pygoscelis papua papua*) is another race called *Pygoscelis papua ellsworthi* in honor of the late American explorer. In this race, the bill. wings and feet are smaller, *above.*

The genus *Aptenodytes* extends from the subantarctic range of the king penguin to the fully antarctic range of the emperor. The emperor has twice the bulk of the king. but its bill. wings and feet are relatively much smaller than those of the king. a factor favoring heat retention in this species' extremities.

However much these two largest of living penguins look alike as adult birds. their young are strikingly different. Not only are the chicks totally dissimilar in plumage. but their rate of growth is also quite unlike. The king penguin takes nearly a year to lose its down and acquire its first contour feathers. The young emperor accomplishes this change in four to five months. As readers of Dr. Rivolier's account (Natural History, February. 1959) will appreciate, the climatic environment and the annual breakup of the sea ice would make a longer downy stage for the emperor chick impossible. Unless the emperor penguins had thus adjusted. they would long ago have ceased to exist.

Both penguins of this genus lay only one egg. make no nest and carry the egg throughout incubation on top of their feet. warmed by a feathery fold of skin on the belly: this is a patent necessity for the emperor. which broods only on shore-bound sea ice in the darkest and coldest season of antarctic winter. Because of the less severe life zone in which the king dwells, this species would not be so bound by external circumstances. Here is at least a suggestion that the peculiar method of incubation in *Aptenodytes* may be fundamentally genetic rather than environmental. If there were a tropical species of the genus, it, also, might habitually carry its egg on its insteps.

The genus *Eudyptes* completes our postulated circle of radial—certainly not linear—evolution of the living penguins from a forebear resembling *Megadyptes.* Only one of the six species of this genus, the rockhopper. is of circumpolar. although subpolar, range—in low latitudes of the west wind belt. At least. this is true unless one or more of the insular representatives in the New Zealand area should prove to be only a subspecies of the macaroni penguin. which resides in the American and Indian Ocean quadrants of the Far South. The macaroni is the only one of the group that ranges far south enough to cross the south polar circles (in W. Antarctica).

All six species of *Eudyptes* are of broadly similar aspect. their departure one from the other being in the position. hue, length. angle and curvature of the gay plumes worn on the head. There are additional differences in the precise shape of the bill, and in the extent and color of naked skin around the gape of the mouth. Most of the *Eudyptes* penguins have a red or garnet iris. but the eyes of the New Zealand fiordland species (*pachyrhynchus*) are brown. All species of *Eudyptes* are surface nesters, as are those of the genus *Pygoscelis.*

All of the foregoing presents no more than a sketchy outline of complex evolutionary processes. Among certain groups of animals—such as the horses and. still more, the marsupials—science has uncovered a reasonably sequential record of descent from the beginning of the Tertiary, or even from levels in the preceding Age of Reptiles. The corresponding history of the penguins is broken by great gaps. some of which may be narrowed by future findings in yet unexplored fossil beds.

In any case. the pattern is even now consistent. when compared with that of other animals. We find that, between the remote period of penguin origin and the present time, these birds have always occupied an oceanic belt in the Southern Hemisphere, and that biogeographic differentiation has enabled them to widen their family range—to the equator in one direction. and to coasts of the most frigid earthly temperatures in the other. A single type of bodily form and of subsurface swimming has remained common to all of them. But adaptive radiation has changed their locomotion on land or ice so that some penguins walk, some progress by jumps (whence the name "rockhopper"), some "toboggan" on ice or snow. some can climb the faces of steep cliffs and some can leap like salmon when they shoot out of the sea to reach the shore.

Likewise. their modes of nesting and of hatching eggs. together with the number of eggs in a clutch, have come to vary so that each species is in tolerable harmony with its respective habitat. And. finally. their food. which is captured only beneath the surface of salt water, also varies to match the resources of the chosen feeding range. Some species of penguins subsist almost or quite exclusively upon squids. some upon shrimplike crustaceans. and others prevailingly upon schooling fish.

Yet. for all this variety. a man who has ever seen *any* penguin is not likely to mistake any other penguin—however different it may be in small respects—for any other kind of bird.

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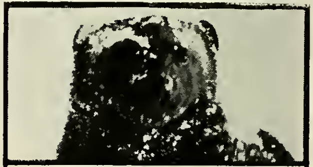

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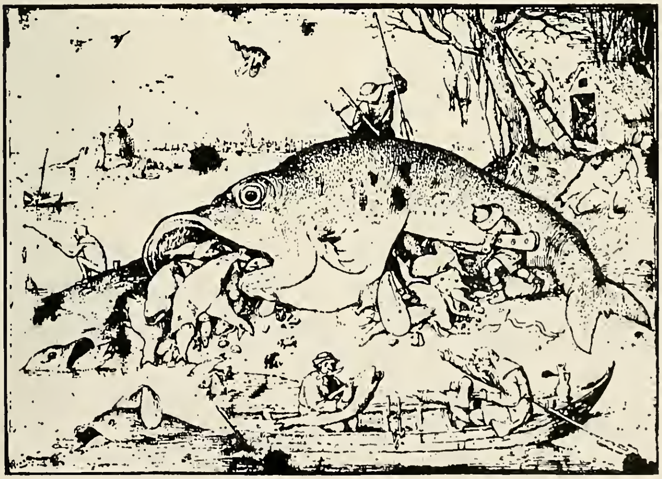
(Continued from page 117)

tremendous cost in money and effort) is one of them. Others are the chestnut blight, brought from Asia to America on nursery stock, with consequences that are well known; the European starling, which, after several failures, was successfully introduced into New York in 1891; and, to balance this, the North American muskrat, which spread over Europe from five individuals brought to Czechoslovakia in 1905. Elton's fifth example is *Spartina townsendii*, a strong-growing cord grass or rice grass, which has colonized many stretches of English tidal mud flats and is a natural hybrid between a native English plant and an introduced American species. Elton next discusses the sea lamprey, which presumably reached the Great Lakes after the construction of the Welland Canal in 1829, but did not explode in the newly available habitat until a hundred years later. His final case history concerns the Chinese mitten crab, which somehow has reached, and multiplied in, several European river systems.

These seven examples illustrate the kinds of things that happened as a consequence of deliberate or accidental introductions *through human agency*, and Elton stresses the moral they point: "Between them all they cover the waters of sea, estuary, river and lake; the shores of sea and estuary; tropical and temperate forest country, farm land and towns." Man, with his restless movements from continent to continent, has broken down zoogeographical barriers around the world, with all sorts of consequences. "We must make no mistake," Elton emphasizes, "we are seeing one of the great historical convulsions in the world's fauna and flora."

Elton puts this present event in geological perspective in a chapter entitled "Wallace's Realms: the Archipelago of Continents," a capsule statement of the history of animal distribution. He makes this excursion into the past because, "if we are to understand what is likely to happen to ecological balance in the world, we need to examine the past as well as the future. If, during the last 100 million years, the flora and fauna of the world had been able to develop in such a way that every organism had a good chance of spreading to all parts of the globe that its characteristics could tolerate, so that there was only one species for each kind of ecological situation, the potentialities for future change under the impact of man's activities would be different." But cosmopolitan distribution has not been easy to achieve, at least since the Cretaceous era, and most land organisms have been cooped up on particular continents or islands or parts of continents. Human transportation is now providing a new kind of connecting system which allows parts of these separated biotas to mingle.

This new kind of interland access is limited by the characteristics of man and his transportation system, but it is not really small—Elton quotes David Fairchild to the effect that the United States Office of Plant Introduction has introduced nearly 200,000 named species and varieties of plants into this country. This, as Elton remarks, "... is a very solid contribution to the vegetation of nations!" And animals have followed the


"The big fish eat the small ones," *after* Brueghel, depicts principle of food-chains.

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plants. Elton examines the spread of the Japanese beetle, the Argentine ant, the Colorado potato beetle and a number of other plant-eating insects that have achieved intercontinental dispersal as a consequence of human activities.

Elton then turns from continents to "The Fate of Remote Islands," where the effect of introductions by man is most striking. He looks at Easter Island and at the three remote pinnacles of the Tristan da Cunha group, but devotes most of his discussion to Hawaii and New Zealand—where both alien and indigenous biotas have been best studied. Yet, after reading Elton's summary, one is impressed by how much remains to be learned, and by the potential usefulness of the knowledge that could be gained from the vast, unplanned experiments in these island laboratories.

As Elton remarks, "The fate of remote islands is rather melancholy, even after one has made allowances for all the human excellence that has remained or developed again in some of them after our invading civilizations settle down. The reconstitution of their vegetation and fauna into a balanced network of species will take a great many years. So far, no one has even tried to visualize what the end will be. What is the full eco-system on a place like Guam or Kauai or Easter Island? How many species can get along together in one place? What is the nature of the balance amongst them? Can we combine the simple culture of crops with the natural complexity of nature, especially when there is an almost inexhaustible reservoir of continental species that may send new colonists to disturb the scene?" Ecologists, understandably enough, have scarcely begun to think of these questions, let alone to look for the answers.

MAN is a land animal, and when we think of his impact on the rest of nature, we are apt to consider only his effect on terrestrial and fresh-water organisms. So far, man's effect on the seas —which make up three-fourths of the surface of our planet—has, in fact, been relatively trivial. Yet he has effected some "Changes in the Sea," as Elton points out in his next chapter—through the construction of the Suez and Panama canals, and through the movements of his ships, which may carry sessile organisms on their hulls or drifting organisms in their water ballast. But his greatest effect, probably, is through a less obvious activity, oyster culture. This ". . . involves much greater managed interference with the natural habitat than any other kind of fishery, and in this way resembles more the crop or flock cultivation of agricultural land, while most other purely sea fisheries still remain at the hunting stage—depending on knowledge and on restraint but not

Prof. Bates, who teaches zoology at the University of Michigan, devotes special study to human ecology. His latest book is entitled *Coral Island.*

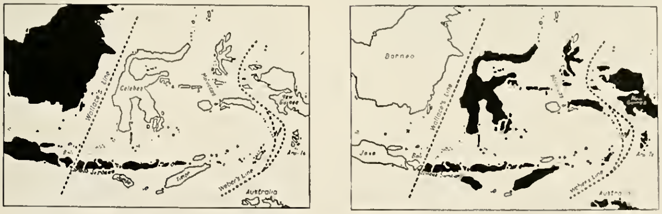
on modification of the habitat in any elaborate way." Elton discusses the effect of oyster culture and oyster traffic at some length. He also discusses another little-known case of human interference with the marine environment—the purposeful and accidental introduction of species, sometimes with explosive results, into the Caspian Sea.

In these first five chapters of his book, Elton is mainly concerned with successful invasions. "But," he points out, "there are enormously more invasions that never happen, or fail quite soon or even after a good many years (like the skylark in America). They meet with resistance." So, in his sixth chapter, "The Balance between Populations." Elton turns to the study of this resistance. He discusses direct measures like quarantine, eradication and control—this last often achieved through the introduction of counterpests—but he is mainly concerned with natural resistance, with the difficulty that any alien finds in penetrating a long-established and balanced community. "An ecological system, like an organized human community, has its separate centres of action—such as the soil and the tree canopy, the marsh and the stream, the fallen log and the bird's nest—but always at some point you can find connexions between them, and these may affect the balance between populations. The invader is therefore working his way somehow into a complex system, rather as an immigrant might try to find a job and a house and start a family in a new country...." The aliens almost always stick to habitats that have been drastically simplified by man: the foreigner has great difficulty displacing the established native. Elton does not quote figures, but H. H. Allan, in a paper published in 1936 on alien plants in New Zealand, estimated that of 603 "naturalized" species, only 48 had been able to compete seriously with native plants in undisturbed habitats—yet isolated New Zealand should be especially susceptible to invasion by aggressive foreigners.

This is, of course, partly an academic question, since so much of the earth's surface is drastically altered and simplified by man and is likely to continue so, providing ample opportunities for foreign invasion. But such a situation offers the ecologist excellent opportunities for studying the subtle problems of competition among organisms, problems we are still far from understanding.

Elton moves from his discussion of ecological resistance, of the complex and obscure factors governing competition, to a consideration of "New Food-chains for Old." He remarks that "With land in cultivation, whether pastoral, ploughed, or gardened, the earnest desire of man has been to shorten food-chains, reduce their number, and substitute new ones for old. We want plants without other herbivorous animals than ourselves eating them. Or herbivorous animals without other carnivorous animals sharing them. Only in the sea do we still depend on nearly full, natural food-chains to supply our wants." But man is only slowly learning how to manage his shortened food-chains so as to prevent overgrazing, erosion, and deterioration of the land's productivity.

Man has manipulated food-chains in other ways, particularly by widespread, deliberate introduction of counterpests to control introduced pests—a subject which Elton discusses in some detail and with numerous examples, successful and otherwise. Increasingly, however, we have come to depend on chemical poisons for the control of pests. We are beginning to find all sorts of indirect and unexpected consequences; but here again we need more ecological study. "No realist would for a moment suppose that either counterpests or chemical warfare can be abandoned, but both can be much modified and adapted to the equal realities of the ecological scene, and the very delicately organized and interlocking system of populations that lies within it."



Wallace's line divides range of animals moving west from Australian area and east from Asia. *Left*, a woodpecker species has crossed line; cockatoos, at *right*, have not.

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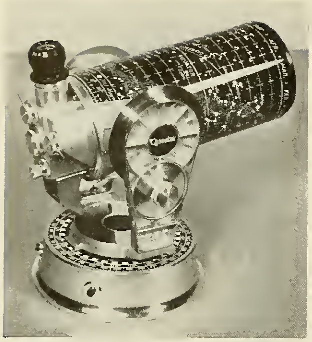

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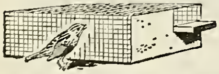

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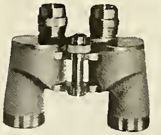

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Summing up, Elton considers "The Reasons for Conservation." Here, he finds three different points of view. The first—usually given pride of place only in India—might be called religious, and concerns the rights of animals. In this connection, Elton quotes Schweitzer, who said that "The great fault of all ethics hitherto has been that they believed themselves to have to deal only with the relation of man to man."

The second point of view might be called esthetic and intellectual. "You may take the point of view," Elton notes, "that it is all so interesting and beautiful that it should be preserved, especially preserved for posterity to enjoy."

The third point of view is practical, and is concerned with the most efficient use of biological resources. Elton believes that there need be no great conflict among these different points of view. He rests his case chiefly on the evidence that *the greater the complexity of the biological community, the greater its stability*—evidence from laboratory experiments, mathematical analyses, and the observation of natural and man-altered situations.

If, then, we want to promote ecological resistance to invaders and to prevent damaging explosions in native populations, our best course is to conserve the variety of nature as far as possible. "Unless one merely thinks man was intended to be an all-conquering and sterilizing power in the world, there must be some general basis for understanding what it is best to do. This means looking for some wise principle of co-existence between man and nature, even if it has to be a modified kind of man and a modified kind of nature. This," Elton concludes, "is what I understand by *Conservation*."

NOTE

The article "Polar Realm of the Emperors," by Jean Rivolier, which appeared in last month's Natural History, was a partial digest of Dr. Rivolier's recent book, *Emperor Penguins*. The volume, published in the U. S. by Robert Speller & Sons, New York, is heartily recommended to our readers.

The Editors

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SCIENTIFIC PUBLICATIONS OF
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January — December
1958

The Museum's publications may be classed in three groups: Novitates — pamphlet-sized publications, uniformly priced at $.25; the Bulletin—separate articles, individually priced; and the Anthropological Papers, as well as miscellaneous publications—also individually priced. The following titles have appeared during January—December, 1958:

Aufenberg, Walter. A new genus of colubrid snake from the Upper Miocene of North America. Novitates, No. 1874, 16 pp., 3 figs., 2 tables (February 27)

Barnes, Robert D. North American jumping spiders of the subfamily Marpissinae (Araneae, Salticidae). Novitates, No. 1867, 50 pp., 75 figs. (January 2)

Batten, Roger Lyman. Permian Gastropoda of the southwestern United States, 2. Pleurotomariacea, Portlockiellidae, Phymatopleuridae and Eotomariidae. Bulletin, Vol. 114, art. 2, pp. 153-246, figs. 1-17 pls. 32-42, tables 1-29 (March 3)

Bell, A. Weir. The anatomy of the oligochaete *Enchytraeus albidus*, with a key to the species of the genus *Enchytraeus*. Novitates, No. 1902, 13 pp., 10 figs. (July 22)

Cahn, Phyllis H. Comparative optic development in *Astyanax mexicanus* and in two of its blind cave derivatives. Bulletin, Vol. 115, art. 2, pp. 69-112, pls. 11-27, tables 1-11 (May 5)

Chamberlin, Ralph V., and Willis J. Gertsch. The Spider Family Dictynidae in America North of Mexico. Bulletin, Vol. 116, art. 1, pp. 1-152, figs. 1-37, pls. 1-47 (October 20)

Colbert, Edwin H., and Donald Baird. Coelurosaur bone casts from the Connecticut Valley Triassic. Novitates, No. 1901, 11 pp., 2 figs., 1 table (July 22)

Colbert, Edwin H., and John H. Ostrom. Dinosaur stapes. Novitates, No. 1900, 20 pp., 11 figs. (July 22)

De Castro, Alceu Lemos. *Benthanoscia longicaudata*, a new genus and species of terrestrial isopod of the family Oniscidae (Isopoda, Oniscoidea). Novitates, No. 1884, 7 pp., 14 figs. (March 21)

De Castro, Alceu Lemos. On the systematic position of some American species of *Philoscia* Latreille (Isopoda, Oniscoidea). Novitates, No. 1908, 10 pp., 19 figs. (August 13)

Dowling, Herndon G. Pleistocene snakes of the Ozark Plateau. Novitates, No. 1882, 9 pp. (February 28)

Duellman, William E. A monographic study of the colubrid snake genus *Leptodeira*. Bulletin, Vol. 114, art. 1, pp. 1-152, figs. 1-25, pls. 1-31, maps. 1-25, tables 1-30 (February 24)

Emerson, William K. Results of the Puritan-American Museum of Natural History expedition to western Mexico. 1. General account. Novitates, No. 1894, 25 pp., 9 figs. (July 22)

Emerson, William K., and Warren O. Addicott. Pleistocene invertebrates from Punta Baja, Baja California, Mexico. Novitates, No. 1909, 11 pp., 2 figs., 2 tables (August 13)

Forster, Raymond R. Spiders of the family Symphtognathidae from North and South America. Novitates, No. 1885, 14 pp., 27 figs. (March 21)

Gates, G. E. On a hologynous species of the earthworm genus *Diplocardia*, with comments on oligochaete hologyny and "Consecutive hermaphroditism." Novitates, No. 1886, 9 pp. (March 21)

Gates, G. E. On some miscellaneous lots of earthworms belonging to The American Museum of Natural History. Novitates, No. 1887, 11 pp. (March 21)

Gates, G. E. On some species of the Oriental earthworm genus *Pheretima* Kinberg, 1867, with key to species reported from the Americas. Novitates, No. 1888, 33 pp., table 1 (March 21)

Gertsch, Willis J. The spider family Hypochilidae. Novitates, No. 1912, pp. 1-28, figs. 1-50 (October 6)

Gertsch, Willis J. The spider family Diguetidae. Novitates, No. 1904, 24 pp., 19 figs. (August 13)

Gertsch, Willis J. Results of the Puritan-American Museum expedition to western Mexico. 4. The scorpions. Novitates, No. 1903, 20 pp., 6 tables (August 13)

Gertsch, Willis J. The spider genus *Loxosceles* in North America, Central America and the West Indies. Novitates, No. 1907, 46 pp., 97 figs. (August 13)

Goodwin, George G. Two new mammals from Mexico. Novitates, No. 1871, 3 pp. (February 26)

Goodwin, George G. Three new bats from Trinidad. Novitates, No. 1877, 6 pp., 2 tables (February 28)

Hoff, C. Clayton. List of the pseudoscorpions of North America north of Mexico. Novitates, No. 1875, 50 pp. (February 28)

Hoff, C. Clayton, and Dwain Parrack. Results of the Archbold expeditions. No. 77. Two species of *Megachernes* (Pseudoscorpionida, Chernetidae). Novitates, No. 1881, 9 pp., 2 figs. (February 28)

Jacobson, Morris K. Results of the Puritan-American Museum of Natural History expedition to western Mexico. 3. The terrestrial mollusks. Novitates, No. 1899, 14 pp., 2 figs., 1 table (July 22)

LaMonte, Francesca and others. On the biology of the Atlantic marlins, *Makaira ampla* (Poey) and *Makaira albida* (Poey). Scales of the Atlantic species of *Makaira*, by Francesca R. LaMonte. Notes on the alimentary, excretory and reproductive organs of Atlantic *Makaira*, by Francesca R. LaMonte. Relative weights of some viscera in the Atlantic marlins, by Louis A. Krumholz. Some foods of marlins near Bimini, Bahamas, by Louis A. Krumholz and Donald P. deSylva. Juvenile blue marlin, *Makaira ampla* (Poey), from Miami, Florida, and West End, Bahamas, by Donald P. deSylva. Bulletin, Vol. 114, art. 5, pp. 373-416, figs. 1-14, pls. 75-82, tables 1-7 (March 24)

Lane, Frederico. A new Neotropical genus of Ischiolonchini (Coleoptera, Lamiidae). Novitates, No. 1889, 17 pp., 2 figs. (March 21)

McDunnough, James H. A new species of *Coleophora* belonging to the *duplicis-bidens* group. Novitates, No. 1905, 5 pp., 3 figs. (August 13)

McDunnough, James H. Heretofore unpublished illustrations of coleophorid genitalia, with notes (Lepidoptera). Novitates, No. 1880, 11 pp., 15 figs. (February 28)

McDowell, Samuel Booker, Jr. The Greater Antillean insectivores. Bulletin, Vol. 115, art. 3, pp. 113-214, figs. 1-46, tables 1, 2 (May 5)

Marcus, Ernst. On western Atlantic opisthobranchiate gastropods. Novitates, No. 1906, 82 pp., 111 figs. (August 13)

Moore, Joseph Curtis, New genera of East Indian squirrels. Novitates, No. 1914, pp. 1-5 (October 22)

Moore, Joseph Curtis. A beaked whale from the Bahama Islands and comments on the distribution of *Mesoplodon densirostris*. Novitates, No. 1897, 12 pp., 6 figs., 2 tables (July 22)

Moore, Joseph Curtis. A new species and redefinition of the squirrel genus *Prosciurillus* of Celebes. Novitates, No. 1890, 5 pp. (March 21)

Moore, Joseph Curtis. New striped tree squirrels from Burma and Thailand. Novitates, No. 1879, 6 pp., 2 tables (February 28)

Newell, Norman D. A note on Permian crassatellid pelecypods. Novitates, No. 1878, 6 pp., 3 figs. (February 28)

Nichols, J. T. A new goby and other fishes from Formosa. Novitates, No. 1876, 7 pp., 1 fig. (February 28)

Norris, Kenneth Stafford. The evolution and systematics of the iguanid genus *Uma* and its relation to the evolution of other North American desert reptiles. Bulletin, Vol. 114, art. 3, pp. 247-326, figs. 1-17, pls. 43-6, tables 1, 2 (March 10)

Parkes, Kenneth C. A new race of the blue-headed fantail (*Rhipidura cyaniceps*) from northern Luzon, Philippine Islands. Novitates, No. 1891, 5 pp., 1 fig. (March 26)

Rasquin, Priscilla. Ovarian morphology and early embryology of the pediculate fishes *Antennarius* and *Histrio*. Bulletin, Vol. 114, art. 4, pp. 327-372, figs. 1, 2, pls. 47-74, tables 1, 2 (March 17)

Rasquin, Priscilla. Studies in the control of pigment cells and light reactions in recent teleost fishes. Part I: Morphology of the pineal region. Part II: Reactions of the pigmentary system to hormonal stimulation. Bulletin, Vol. 115, art. 1, pp. 1-68, fig. 1, pls. 1-10, tables 1-5 (April 14)

Rindge, Frederick H. Descriptions of and notes on North American Geometridae (Lepidoptera), No. 3. Novitates, No. 1910, pp. 1-24, figs. 1-26 (October 6)

Rindge, Frederick H. Descriptions of and notes on North American Geometridae (Lepidoptera), No. 2. Novitates, No. 1872, 23 pp., 29 figs. (February 26)

Ruckes, Herbert. New genera and species of Neotropical Discocephaline and halyine pantaomids (Heteroptera, Pentatomidae). Novitates, No. 1868, 27 pp., 4 figs. (January 31)

Schwartz, Albert. Four new frogs of the genus *Eleutherodactylus* (Leptodactylidae) from Cuba. Novitates, No. 1873, 20 pp., 3 figs. (February 27)

Snyder, Fred M. Muscidae from the Bahama Islands (Diptera). Novitates, No. 1893, 4 pp. (March 26)

Snyder, Fred M. A review of New World *Neodexiopsis* (Diptera, Muscidae). The *Ovata* Group. Novitates, No. 1892, 27 pp., 16 figs. (March 26)

Squires, Donald F. Stony corals from the vicinity of Bimini, Bahamas, British West Indies. Bulletin, Vol. 115, art. 4, pp. 215-262, figs. 1-4, pls. 28-43, tables 1, 2 (May 19)

Squires, Donald F., Some Upper Crataceous corals from New Jersey. Novitates, No. 1911, pp. 1-7, figs. 1-6 (October 6)

Squires, Donald F., and Edward J. Hawkins. Type Specimens of invertebrate fossils in the collections of the Department of Geology and Paleontology. 1. Porifera. Novitates, No. 1913, pp 1-22 (October 22)

Stebbins, Robert C. A new alligator lizard from the Panamint Mountains, Inyo County, California. Novitates, No. 1883, 27 pp., 6 figs., 4 tables (March 21)

Stebbins, Robert C., and Richard M. Eakin. The role of the "third eye" in reptilian behavior. Novitates, No. 1870, 40 pp., 14 figs., 4 tables (February 26)

Tanner, James T., and John William Hardy. Summer birds of the Chiricahua Mountains, Arizona. Novitates, No. 1866, 11 pp. (January 2)

Vaurie, Charles. Systematic notes on Palearctic birds. No. 32. Oriolidae, Dicruridae, Bombycillidae, Pycnonotidae, Nectariniidae and Zosteropidae. Novitates, No. 1869, 28 pp., 1 table (January 31)

Vaurie, Charles. Systematic notes on Palearctic birds. No. 33. A second review of *Carpodacus puniceus*, with a study of its plumages, and a supplementary note on *Emberiza schoeniclus*. Novitates, No. 1898, 10 pp., 3 figs. (July 22)

Vaurie, Patricia. A revision of the genus *Diplataxis* (Coleoptera, Scarabaeidae, Melonthinae). Bulletin, Vol. 115, art. 5, pp. 263-396, figs. 1-158, tables 1-5. (October 15)

Zweifel, Richard G. Results of the Puritan-American Museum of Natural History expedition to western Mexico. 2. Notes on reptiles and amphibians from the Pacific coastal islands of Baja California. Novitates, No. 1895, 17 pp., 1 fig. (July 22)

Zweifel, Richard G. Results of the Archbold expeditions. No. 78. Frogs of the Papuan hylid genus *Nyctimystes*. Novitates, No. 1896, 51 pp., 21 figs., 2 tables (July 22)

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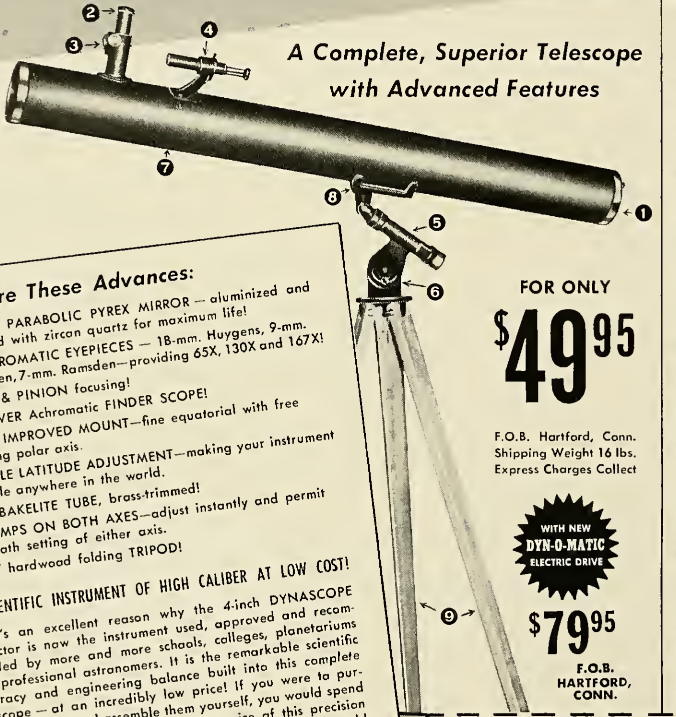

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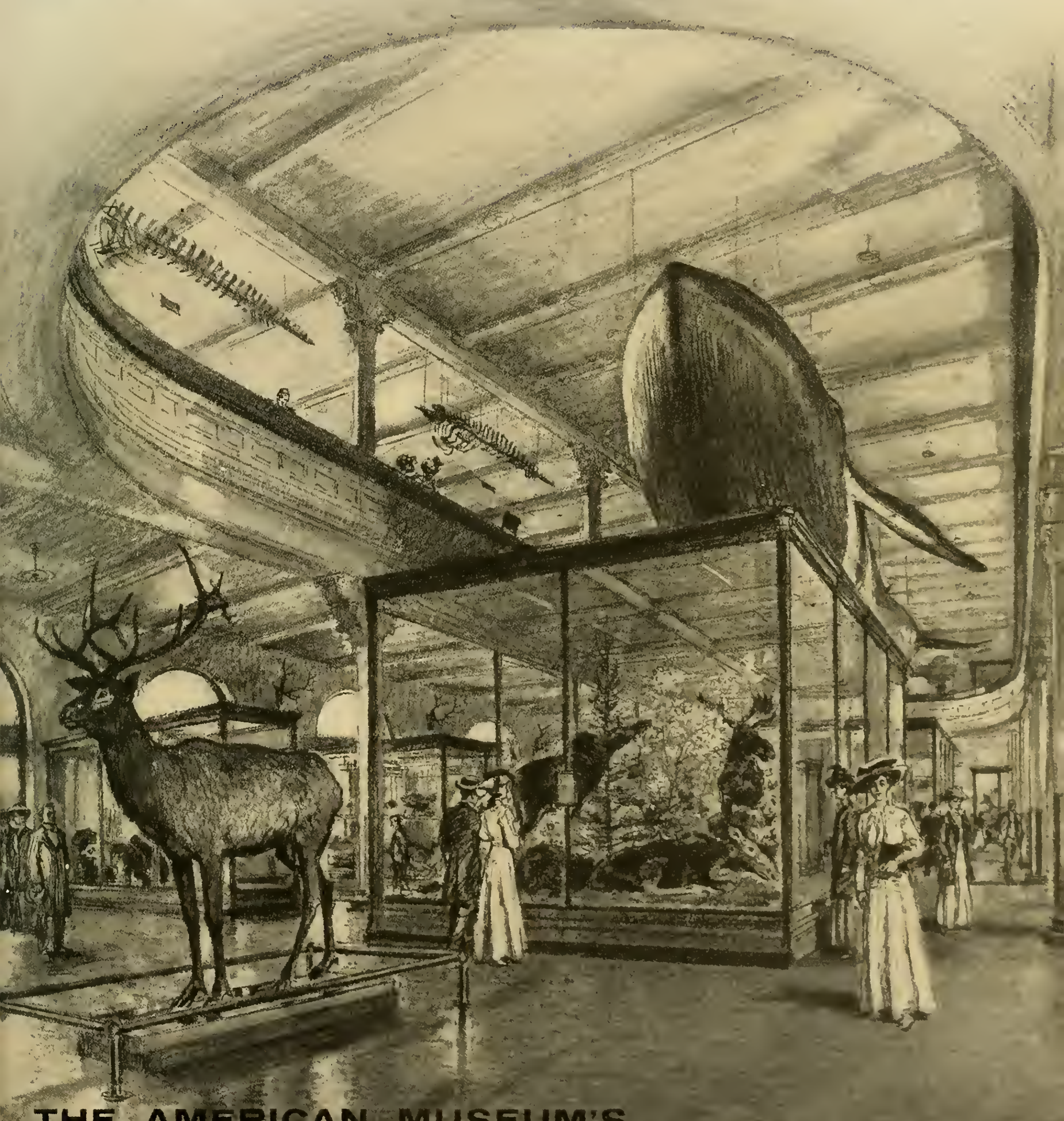

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April 1959

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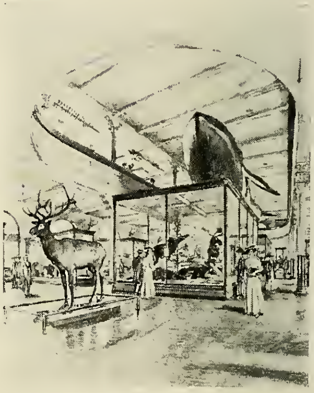

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April of this year marks the ninetieth anniversary of The American Museum of Natural History. For a review of ninety years devoted to the cause of the natural sciences, turn to page 186.

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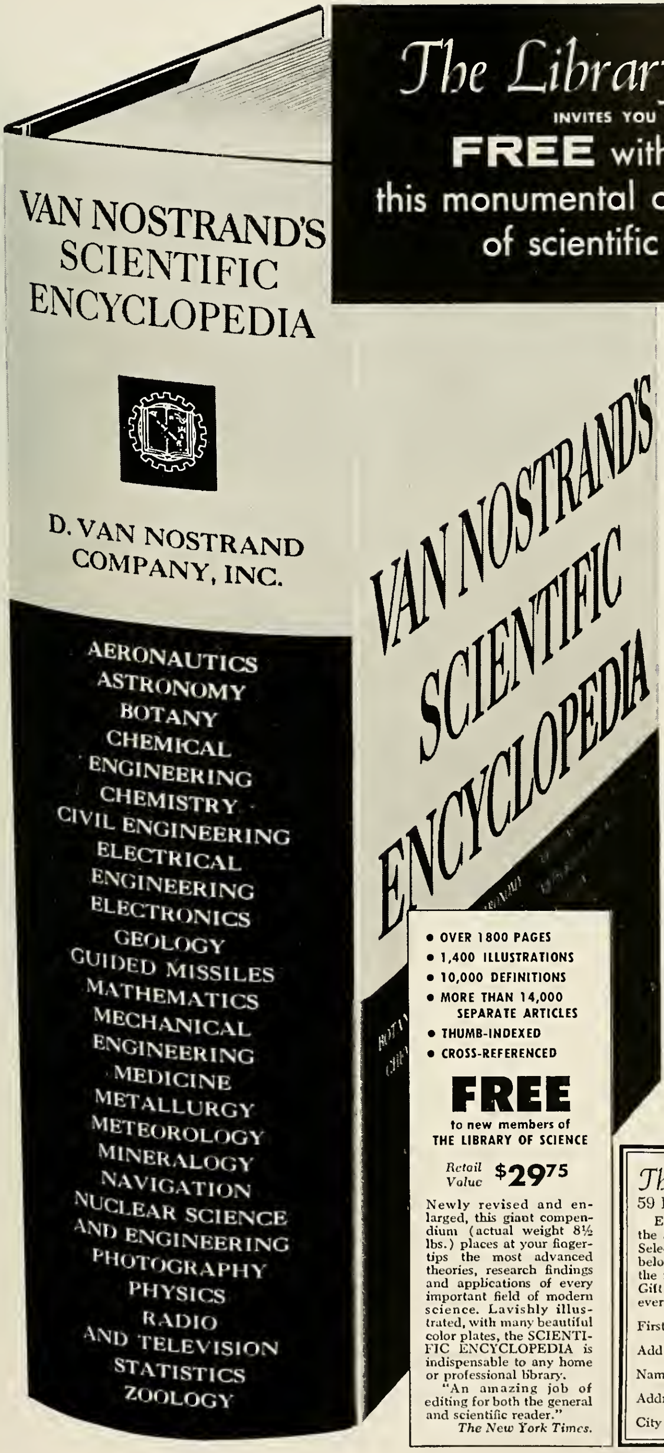
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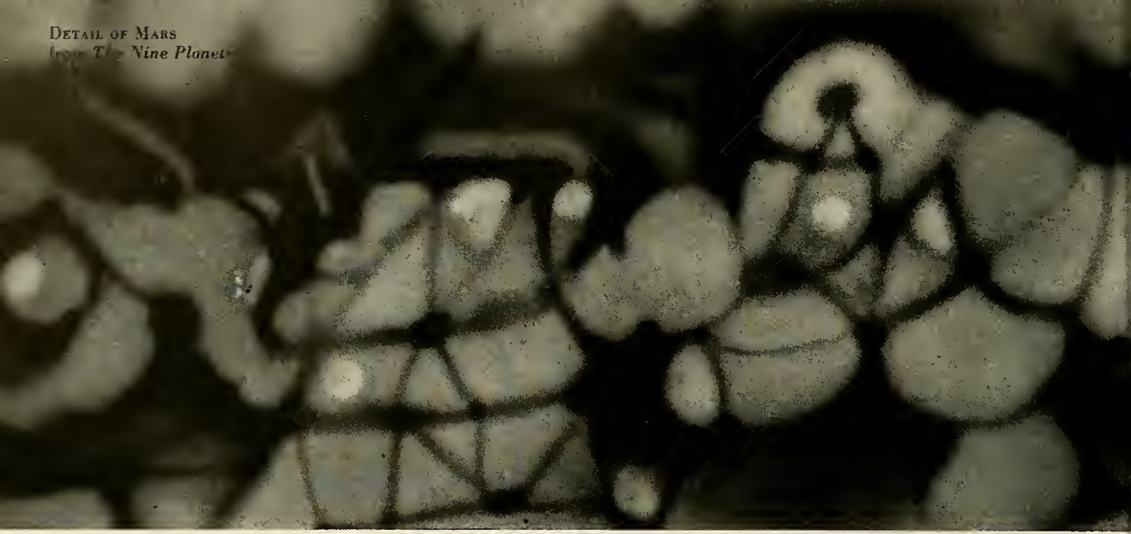

Detail of Mars
from *The Nine Planets*

Reviews TEN BOOKS BY MUSEUM AUTHORS

By Christopher Gerould

LIKE A UNIVERSITY, The American Museum functions on many different levels. By way of its exhibits, its Planetarium, its lectures and publications (including this one), it is an educational institution. Scientifically, through its study collections, field stations, laboratories and libraries, it is an important center for research. Paralleling and reinforcing these activities, it is also an environment conducive to the writing of books — in which the purposes of the Museum are extended both to the public as a whole and to other members of the wide community of natural scientists.

The scope of writing by members of the Museum staff could scarcely be more happily illustrated than by the books reviewed here. Chosen at random—they represent only a portion of the staff's publications in book form over the past eighteen months — their variety is not only a product of the varied interests of the men who wrote them but also a reflection of the Museum's own aim of making knowledge available to everyone, from scientists to school children.

Nothing could better exemplify this width of range than two of the books, both in the field of ornithology. One is destined for the reference shelf and the libraries of specialists; the other for the living room and the bedside table.

For some ten years Charles Vaurie, an assistant curator at the Museum, has been working on *The Birds of the Palearctic Fauna*. A revision of the classical work, Hartert's *Die Vogel der Palaarktischen Fauna*, Dr. Vaurie's volume (Witherby, $16.00; 762 pp.) devotes itself to a systematic listing of the passerine species in the largest of the six great faunal areas of the world—comprising Europe, North Africa and, very roughly, Asia north of the Tropic of Cancer. The average amateur ornithologist will probably never acquire Dr. Vaurie's work, although the North American (Nearctic) fauna has very much in common with the Palearctic. Yet, the volume's painstaking lists of ranges, habitats, subspecies and geographical variations represent the basic data from which other writers will shape popular bird books for decades to come. Indeed, it is not too much to say that the whole structure of the natural sciences rests on the foundation afforded by systematic studies of this kind.

In contrast, *Living Birds of the World*, by E. Thomas Gilliard, associate curator of birds at the Museum, is addressed directly to the amateur. This is the third volume in the "World of Nature" series (Doubleday, $12.50; 400 pp.). Like its predecessors (on reptiles and mammals), it contains extensive descriptions, combined with a profusion of photographs (more than 200 of them in color). Covering 1,500 species (of the some 8,600 species that make up the world's bird population), the text runs to 200,000 words and probably comes as close to a one-volume encyclopedia of ornithology as can ever be expected. One is particularly struck by the remarkably high quality of modern bird photography. This may be owing partly to improvements in photographic equipment and materials, but it also seems likely that the photographer's eye and the bird watcher's have much in common.

Since it first opened, in 1935, the Hayden Planetarium has not only attracted visitors of all ages but has also served, *ex officio*, as the Museum's public relations department for the science of astronomy—answering inquiries from press and public in an increasingly space-conscious age. Two recent books by members of the Planetarium staff usefully extend this public service.

Franklyn M. Branley, associate astronomer, has compressed the important facts about the junior members of our solar system into less than 80 pages in *The Nine Planets* (Crowell, $3.00). Size, position, composition, motions and all the other pertinent data are set down here in direct, simple prose that will not confuse the naked eye or first-telescope amateur. At the same time, the book is meaty enough to be a handy reference for the more advanced. The illustrations, by Helmut K. Wimmer (artist of the Planetarium staff), are handsome and particularly effective in providing a tri-dimensionality that makes such relationships as elongation and lunar and planetary phases obvious at a glance.

Question-and-answer is a common device in writing popular science texts—

Mr. Gerould, a regular contributor of reviews to Natural History, has reported developments in many fields of science for the past two decades.

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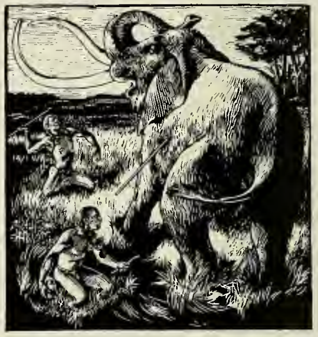
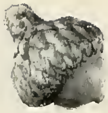
and not always a good one. James S. Pickering, assistant astronomer of the Planetarium, seems to have been aware of this in preparing *1001 Questions Answered About Astronomy* (Dodd, Mead, $6.00; 420 pp.) He has managed to write a book that remains systematic and readable despite the persistent question marks demanded by the Dodd, Mead series to which he has contributed.

The result is the best general astronomical work for the beginner that this reviewer has seen. From Question 1 ("What is the sun?") to Question 1019 ("What books are there for further reading in Astronomy?") Pickering covers the field—always keeping in mind that, in its own way, the mythology of the constellations is quite as interesting as the nature of Cepheid variables, and dealing faithfully with both.



Mammoth is from *Millions of Years Ago.*

Teaching has been characterized as the other half of the scientist's life, and no survey of Museum writing can omit textbooks. One recently published example is *Principles of Zoology* (Oxford, $7.50; 667 pp.)—the work of John A. Moore, a research associate who is also a professor at Barnard and Columbia. The other, a first-year biology text with the deliberately inclusive title *Life*, is a collaboration whose senior author is George Gaylord Simpson, curator of fossil mammals and birds at the Museum. His co-authors are Colin S. Pittendrigh, of Princeton, and Lewis H. Tiffany, of Northwestern (Harcourt, Brace, $7.50; 845 pp.). The review of textbooks is properly a task for a teacher, automatically disqualifying this reviewer (who would be disqualified anyway, as a member of an older generation unable to comprehend the combination of folksiness, hard sell and Hollywood production values that seems to spell success in textbook publishing in these years After Dewey). This is merely to say that the well-organized, factual and—let us face it—rather dry approach of the zoology text seems more attractive to him than the apparent pre-



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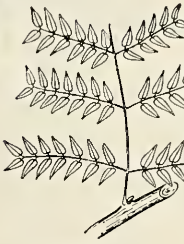

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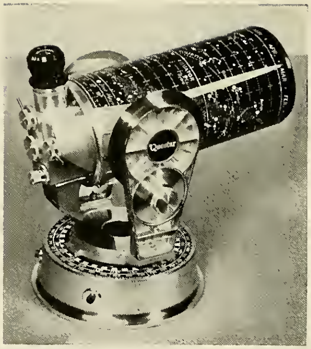

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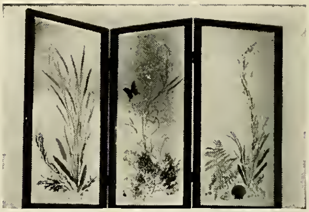

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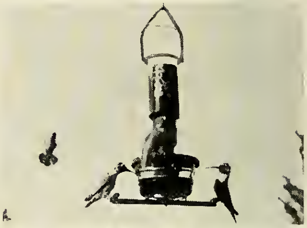

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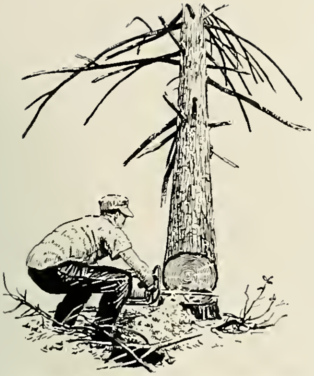

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occupation of *Life* with hammering home the fact that biology is fascinating.

THE undeniable fascination of biology is nowhere more apparent than in the current tendency for specialists in widely separated fields of research to sit down together, compare notes and learn from each other. Such "interdisciplinary" meetings sometimes bring together physical and natural scientists, but more often explore the common ground between disciplines within biology that have become widely separated in a period demanding specialization.

One of the more interesting and fruitful of these *rapprochements* has been between the students of behavior, themselves a diverse group, and the students of evolution. In the last decade it has been realized that the behavior of animal families and genera often appear to be as specific and typical as their physical structures. An obvious possibility is that exploration of comparative behavior may shed new light on the mechanisms of evolution. Such was the seminal idea behind two conferences, held in 1955 and 1956, which are reported in *Behavior and Evolution* (YALE, $10.00; 557 pp.). This volume, edited by Anne Roe and George Gaylord Simpson, collects and comments on a number of the papers presented at the conferences. No blinding illuminations seem to have occurred but, as the papers amply show, psychologists, anthropologists, geneticists and workers in half a dozen other specialties are finding their work much broader in implication than had appeared earlier.

A major objective of the Museum's program has been to encourage the natural interest that most children have in natural history. Two recent publications by members of the staff are addressed particularly to this audience.

In *The Golden Book of Nature Crafts* (SIMON AND SCHUSTER, $1.95; 68 pp.).

(Continued on page 236)

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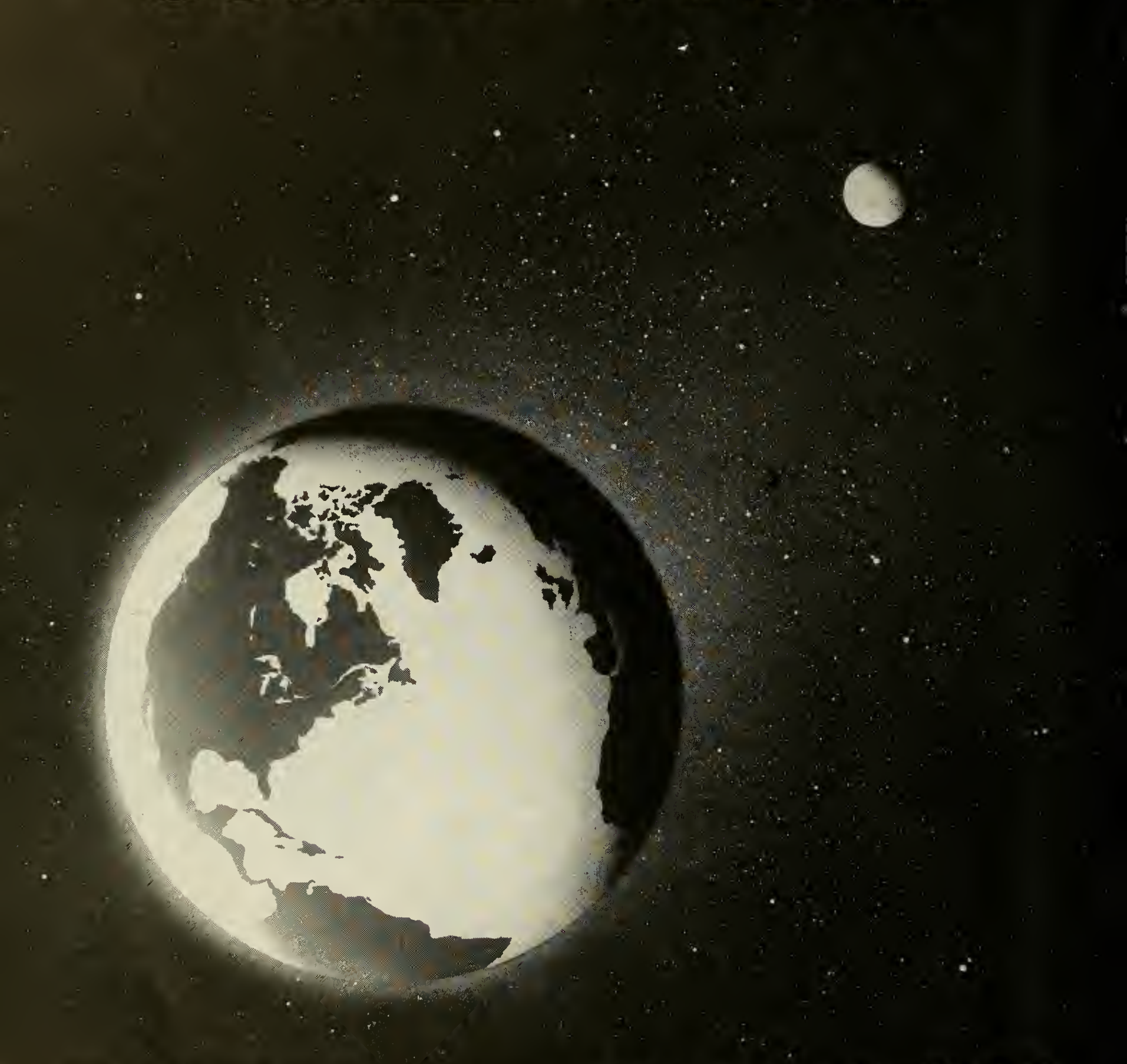
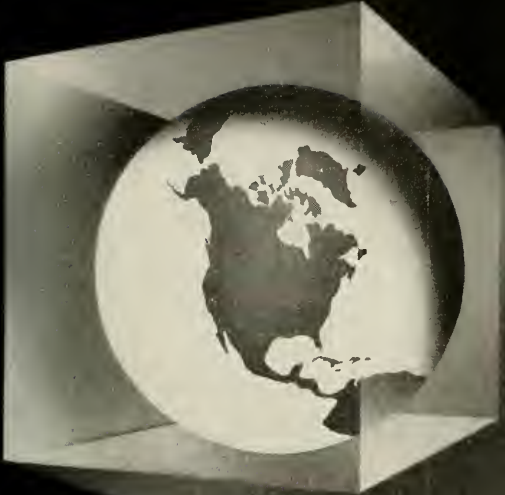
COSMIC STEPS



MAN tends to be egocentric: his view of the universe around him is similarly self-centered—geocentric. However, in the light of present-day conceptions of the universe, this perspective is changing rapidly.

Various methods for developing our understanding of the size of the solar system—and of the way our solar system fits into our galaxy, the Milky Way and, in turn, into the universe—have been employed. In 1957, the John Day Company published *Cosmic View*, a book by Kees Boeke, a Dutch schoolteacher, which gave a picture of the universe in forty steps—from the microscopic through the macroscopic. With kind permission of the publisher, Boeke's plan is modified in this presentation—which begins some 50,000 miles from earth and continues far out into our galaxy and beyond. Helmut Wimmer, artist of The American Museum—Hayden Planetarium, has done three-dimensional drawings to further dramatize Boeke's conception.

Above, we see the earth and the moon, brightly illuminated by the sun, which is over the left shoulder of the viewer. The sunlight reaches to the Pole, as it would during spring and fall. The moon, earth's natural satellite, is in the position it occupies during the full-moon phase.

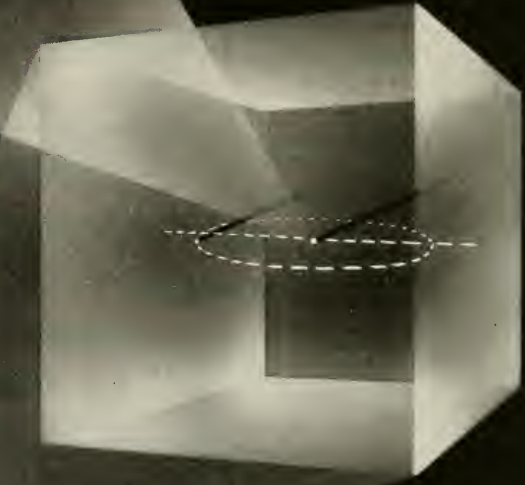


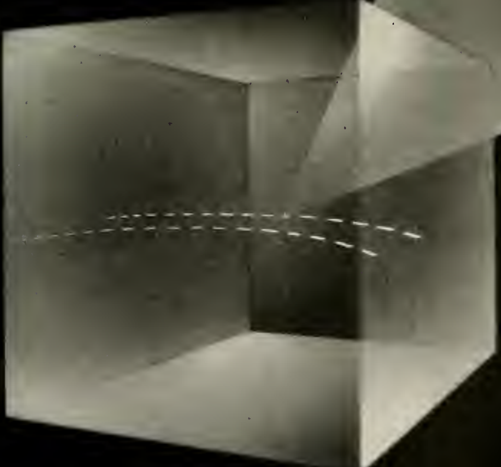
EARTH FROM 50,000 MILES

Our own planet, *left*, is not especially impressive in the family of nine planets which revolves about the sun. Four planets are larger than earth, and four are smaller. The smallest is Mercury, whose equatorial diameter is 3,100 miles; and the largest, Jupiter with an equatorial diameter of 86,850 miles. The diameter of the earth is 7,899 miles from Pole to Pole; 7,926 miles through the equator. Cloud banks, normally present, have, of course, been omitted.

EARTH AND THE MOON

We now move ten times farther into space; and from some 500,000 miles away, the earth–moon system is completely visible. Because of our outward jump, the earth—which filled the preceding cube—has here become the small, central dot. The sun, far toward the lower left, lights both bodies, and both earth and moon cast shadows out into space. The straight dashed line represents a portion of the orbit of earth about the sun. The ellipse shows the orbit of the moon.



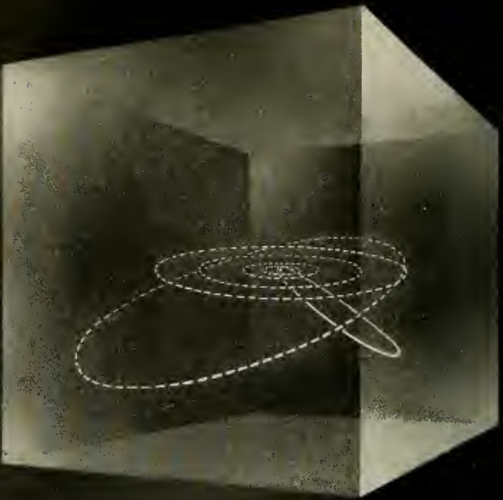


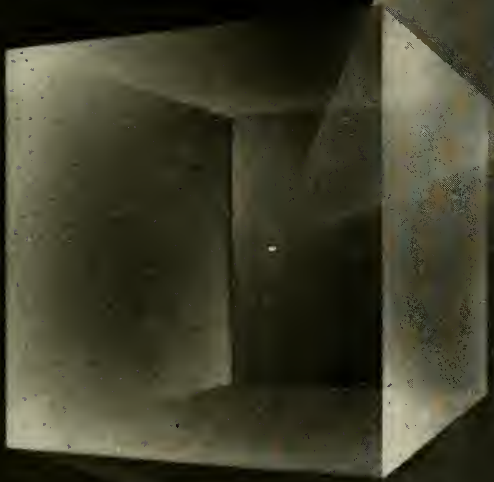
EARTH AND ITS NEIGHBOR PLANET

Of the nine planets, Venus can come nearest earth—at times, it is only 26 million miles away. Venus is sometimes called our sister planet because its diameter (7,700 miles) approximates ours. We have never seen Venus' surface, for it is covered by dense, opaque clouds in its atmosphere. Presented here is a portion of the two planets' orbits as they would appear when viewed from some 50 million miles away—100 times farther away than in the preceding view.

ORBITS OF THE OUTER PLANETS

We move a hundred times still farther out—to a point some 5 billion miles away, whence our solar system can be viewed whole. The dashed lines represent the orbits of the five outermost planets—Jupiter, Saturn, Uranus, Neptune and Pluto. The orbits of the inner planets—Mercury, Venus, Earth, Mars—are all contained within the small central dot. The solid line represents the orbit of Halley's comet, which is now moving toward us and should be visible in 1985—86.



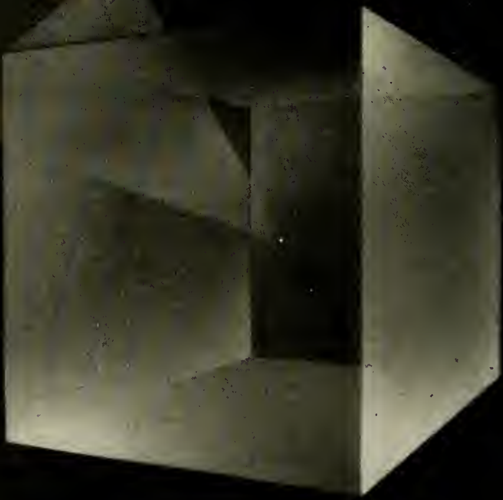


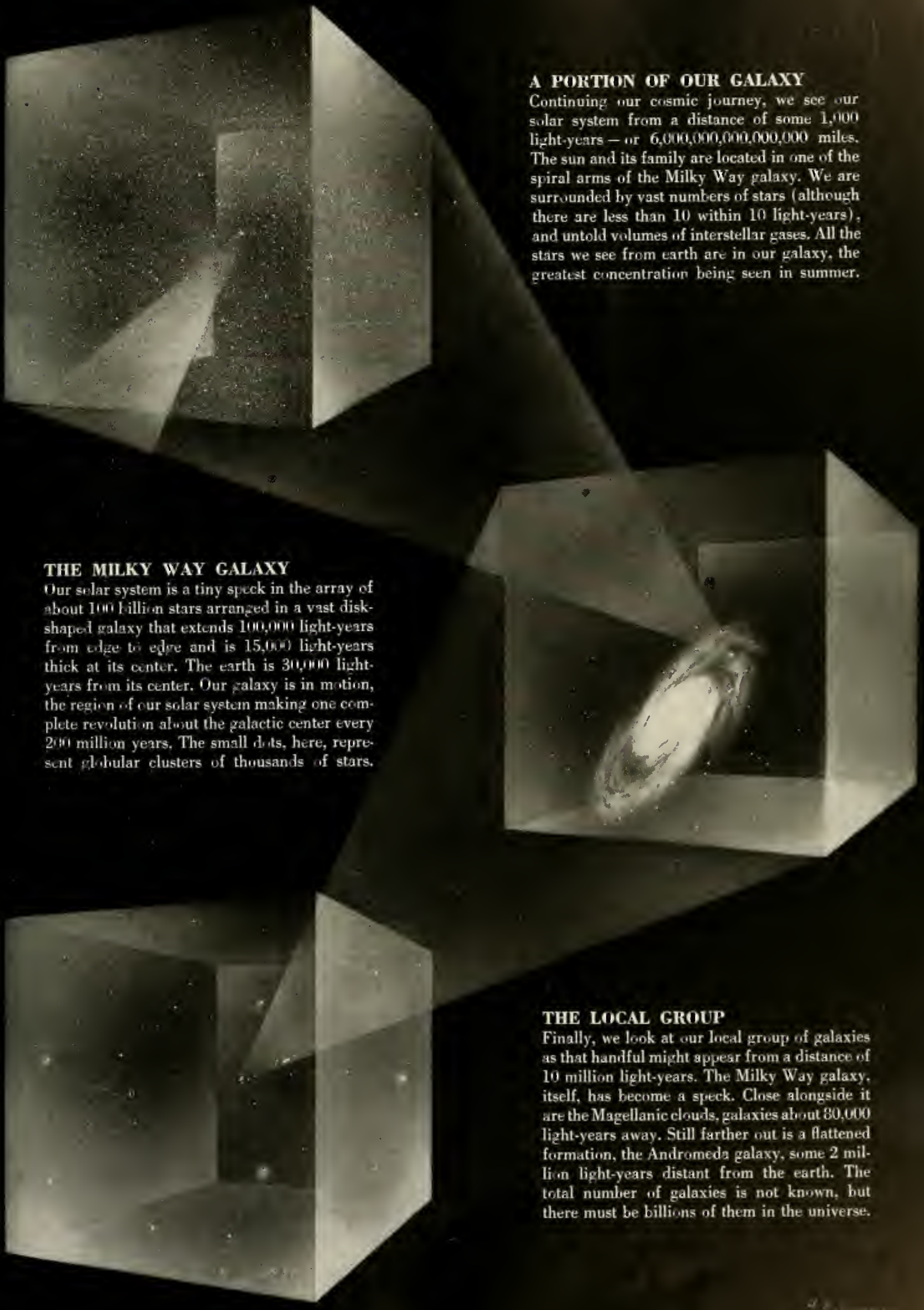
THE SOLAR SYSTEM ALONE

Here is the solar system as it would appear to an observer some 500 billion miles away. The sun, its nine planets, 31 natural satellites, some 1,500 asteroids whose orbits have been determined, and countless numbers of meteoroids and comets all become this insignificant speck. In this drawing, we should also see multitudes of stars in the background, beyond limits of the cube. However, these stars have been omitted, to emphasize our empty immediate surroundings.

OUR NEAREST NEIGHBOR

Our next jump is some 10 light-years into space. Now we see our solar system, together with the star nearest our sun—some 26 million million miles away—Alpha Centauri, a bright double star. To represent such vast distances, astronomers use as a measuring unit the light-year—the distance light travels in one year. Traveling 186,327 miles a second, light requires 4.3 years to cover the distance separating these two dots, i.e., from Alpha Centauri to the solar system.





A PORTION OF OUR GALAXY

Continuing our cosmic journey, we see our solar system from a distance of some 1,000 light-years — or 6,000,000,000,000,000 miles. The sun and its family are located in one of the spiral arms of the Milky Way galaxy. We are surrounded by vast numbers of stars (although there are less than 10 within 10 light-years), and untold volumes of interstellar gases. All the stars we see from earth are in our galaxy, the greatest concentration being seen in summer.

THE MILKY WAY GALAXY

Our solar system is a tiny speck in the array of about 100 billion stars arranged in a vast disk-shaped galaxy that extends 100,000 light-years from edge to edge and is 15,000 light-years thick at its center. The earth is 30,000 light-years from its center. Our galaxy is in motion, the region of our solar system making one complete revolution about the galactic center every 200 million years. The small dots, here, represent globular clusters of thousands of stars.

THE LOCAL GROUP

Finally, we look at our local group of galaxies as that handful might appear from a distance of 10 million light-years. The Milky Way galaxy, itself, has become a speck. Close alongside it are the Magellanic clouds, galaxies about 80,000 light-years away. Still farther out is a flattened formation, the Andromeda galaxy, some 2 million light-years distant from the earth. The total number of galaxies is not known, but there must be billions of them in the universe.

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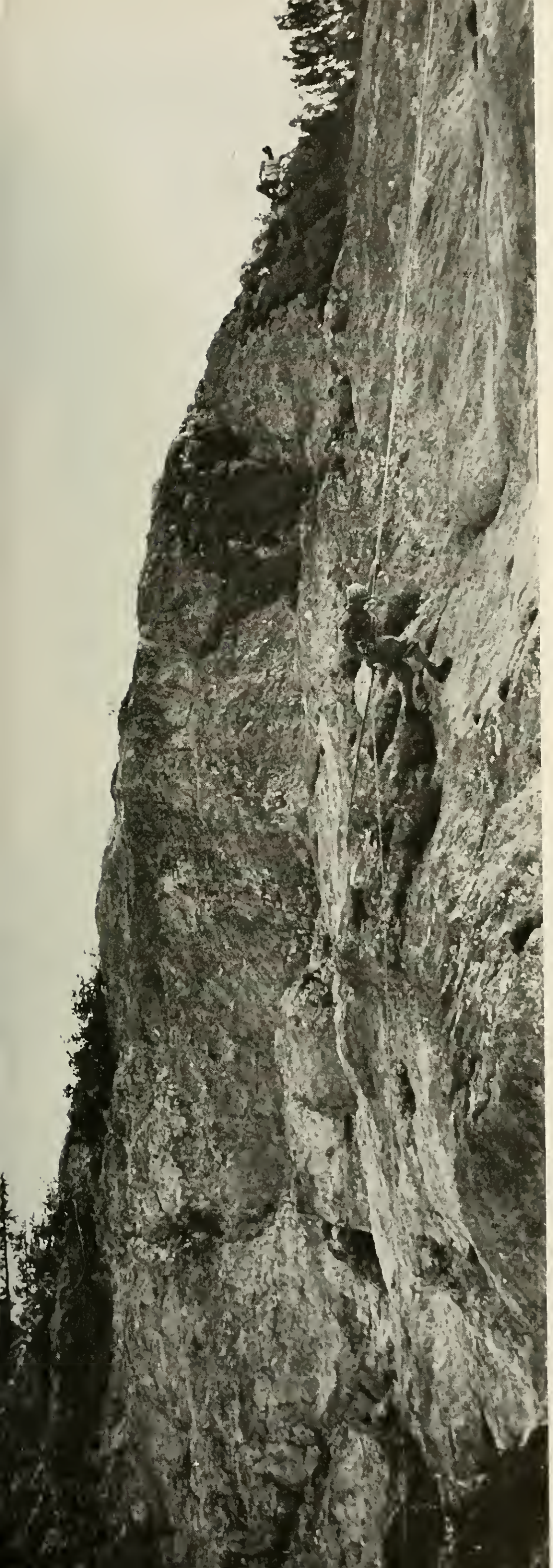


Special nylon rope had to be used to reach the nest, tied in such a way that Jüsy could grip rock during entire descent.

Banding in the Alps

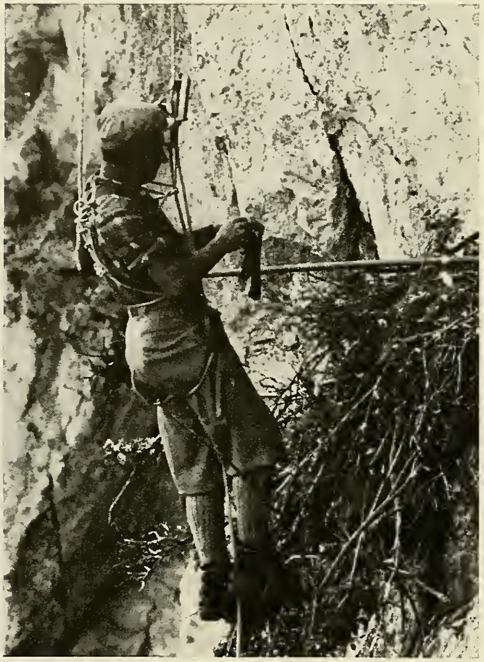
A Swiss ranger leads a risky life

BIRD-BANDING, which seems to have begun in Europe in the late 1800's, is today a world-wide occupation. In North America alone, where upwards of 7,000,000 birds have been banded, there are over 2,000 active banders: and activity is continuing at a rate of about 350,000 birds a year.

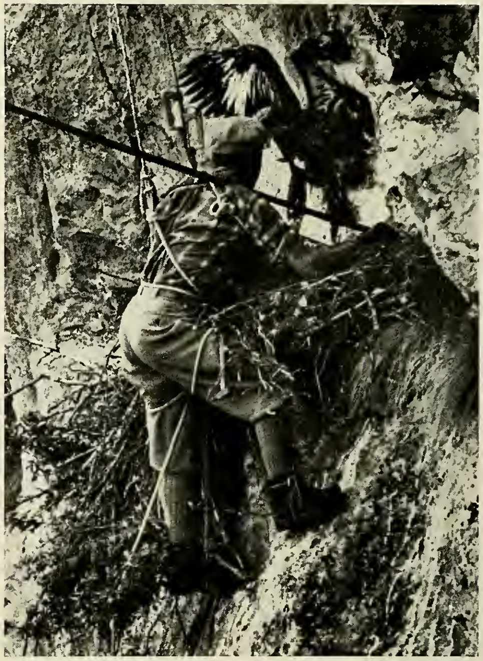
The importance of banding is considerable. It enables us to learn more about the shifts and interrelations of animal populations, about the routes traveled by migratory birds and about bird behavior in general. And the longevity of wild birds may be far better understood if we study wild birds themselves, not birds in zoos and sanctuaries.

This activity has its inconveniences, but even its most ardent enthusiast will agree that it usually requires more patience than heroism. Not so in the Swiss Alps, where rangers risk their lives in their efforts to learn more about the vanishing eagle. One such intrepid mountaineer, Adolph Jüsy, is seen at work in the photographs on these pages. They were taken with a telescopic lens by Albert Winkler.

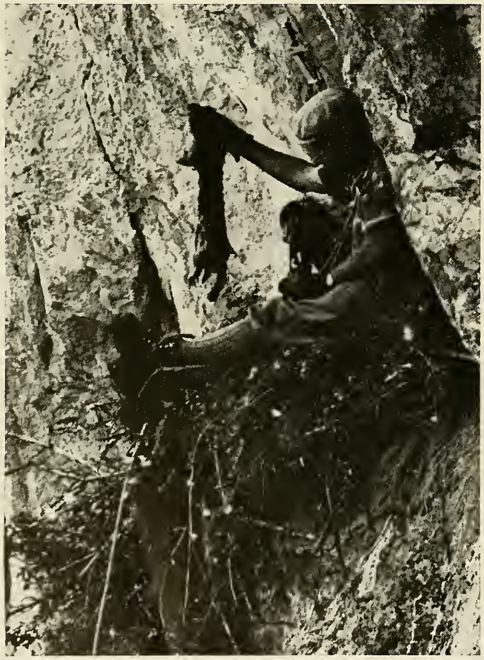
Sheer precipice of a mountain in central Switzerland is seen at left as Jüsy begins his perilous descent to eagle's nest.



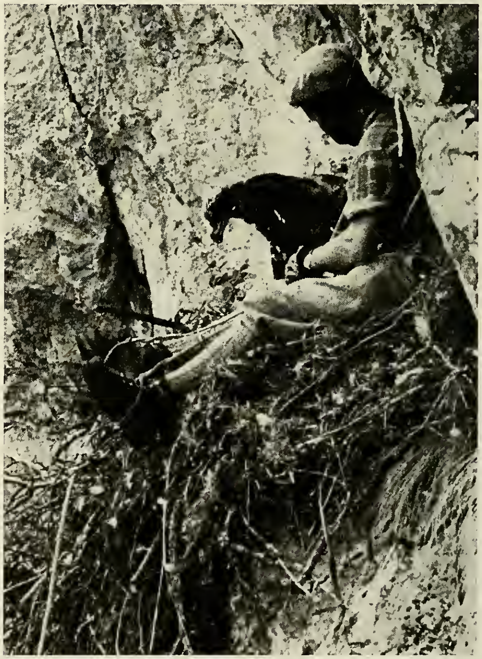
Leather gloves are drawn on by Jüsy before he approaches eagle — the only protection ranger has in case bird attacks.



Eagle spreads wings as intruder Jüsy enters nest. Size of aroused bird adds to the hazards of risky mountain work.



Eagle's victim — in this case a marmot — is displayed by Jüsy, who has pulled himself over to nest with his stick.



Eagle is banded easily, having become calm again after first moment of excitement. *Right*, six-foot wingspread is shown.

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An Act

To incorporate the American Museum of Natural History.

Passed April 6. 1869.

The People of the State of New-York, represented in Senate and Assembly do enact as follows:

Section 1. John David Wolfe, Robert Colgate, Benjamin H. Field, Robert L. Stuart, Adrian Iselin, Benjamin B. Sherman, William A. Haines, Theodore Roosevelt, Howard Potter, William T. Blodgett, Morris K. Jesup, D. Jackson Stewar J. Pierpont Morgan, Anson G. P. Dodge, Charles A. Dana, Joseph H. Choate and Henry Parish, and such persons as may hereafter become

The First Ninety Years

THE AMERICAN MUSEUM CELEBRATES AN ANNIVERSARY

By ALDEN STEVENS

IN 1869, the Suez Canal opened and a golden spike at Promontory Point linked the oceans of North America by rail. Woman suffrage was introduced in Wyoming Territory that year, and General Ulysses S. Grant became the eighteenth President.

In this same year, Albert Smith Bickmore achieved the goal of which he had vowed that he "would work for nothing else by day and dream of nothing else by night." His dream was The American Museum of Natural History, of which the Act of Incorporation appears, *opposite*.

Rarely has a scientific institution of a radically new kind been sponsored and enthusiastically backed by a group of such distinguished citizens. The original incorporators were not men of science, but men of affairs. The list included Theodore Roosevelt (father of President T. R.): Joseph H. Choate, lawyer–diplomat; Charles Anderson Dana, publisher of the *New York Sun;* Morris K. Jesup, banker (and later the Museum's third president); J. P. Morgan, financier; Robert Colgate, soap and paint manufacturer; and J. D. Wolfe, merchant and philanthropist.

Two years after incorporation, the Museum opened—in the old Arsenal Building (now part of the Zoo) in New York's Central Park. Six years later, it moved to the first unit of its present home and, on December 22, 1877, opened to resounding oratory and fashionable acclaim.

WHAT IS "NATURAL HISTORY"? In 1869 it was taken to mean the description, study and classification of natural objects, living and inanimate: birds, mammals, reptiles and fishes; rocks and all the other things, great and small, that make up nature. The term has gone far beyond that now. In The American Museum of Natural History, it means the entire, interrelated natural world, in all its complexity. Indeed, the term extends to embrace the universe.

What is a museum? To the Greeks it was a temple of the Muses, where art and science—the sublime gifts of mankind alone — could reach their highest development. A true museum is not merely a building that houses specimens, for these, without thinking men and women, are nothing.

THIS Museum is such a group of men and women — working, exploring, analyzing and educating. In the beginning, ninety years ago, it was two men: Bickmore, the Superintendent (the later title was Director), and J. B. Holder, his sole assistant. Now it is hundreds, attacking problems that range from insect behavior to the radio sounds of space, and relating these things to the evolution of life and the role of man in nature.

When the Museum was just newly opened, well-known New York diarist George Templeton Strong took stick in hand and strolled up to look it over. "It contains much that is interesting and new (to me)," he wrote, "but the cases seem unnecessarily crowded." Strong was right: the cases were crowded. Bickmore had much material and very little space. He learned the museum business as he went along.

IN the nineteenth century, most museums were simply collections of things. Today, this Museum is a collection of truths and ideas—dramatized and made clear by the display of things in skillful arrangement.

The original crowded cases soon gave way to a startlingly new idea: the habitat group—of which the first showed a pair of robins, in lifelike attitudes over a nest with eggs, built on apple boughs. Mrs. E. W. Mogridge, from the British Museum, constructed this in the 1880's, and with it started the policy of realism in presenting nature, most recently exemplified in the Hall of North American Forests. No longer were birds and animals merely stuffed and plants displayed as dry cuttings: natural positions and colors were re-created. In time, the Museum's exhibits became unfettered, natural unities.

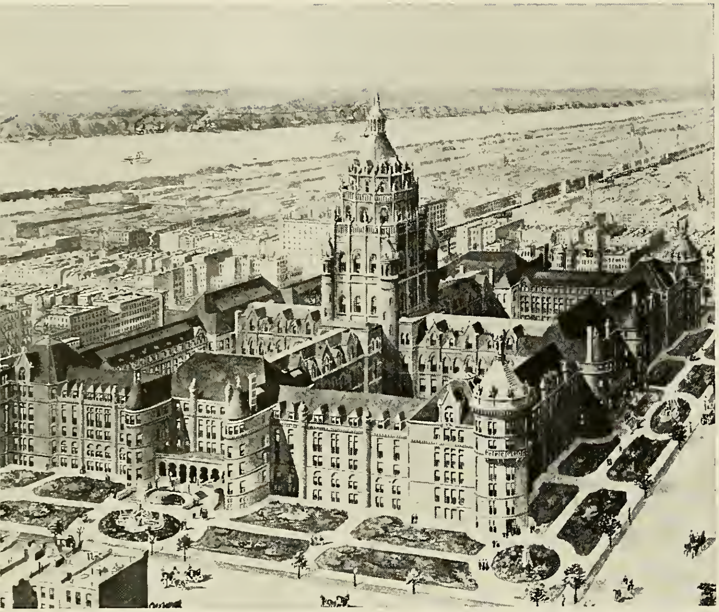
RESEARCH led to new concepts of the earth's past. Exploration probed all parts of the world, returning with prizes to be studied and exhibited. Here were the facts about the natural world laid bare for all to see. The Museum was succeeding in a realization of Albert Bickmore's dream.

A student of the American Scene, MR. STEVENS recently appeared on these pages with a study of T.R.'s role as the father of American conservation.

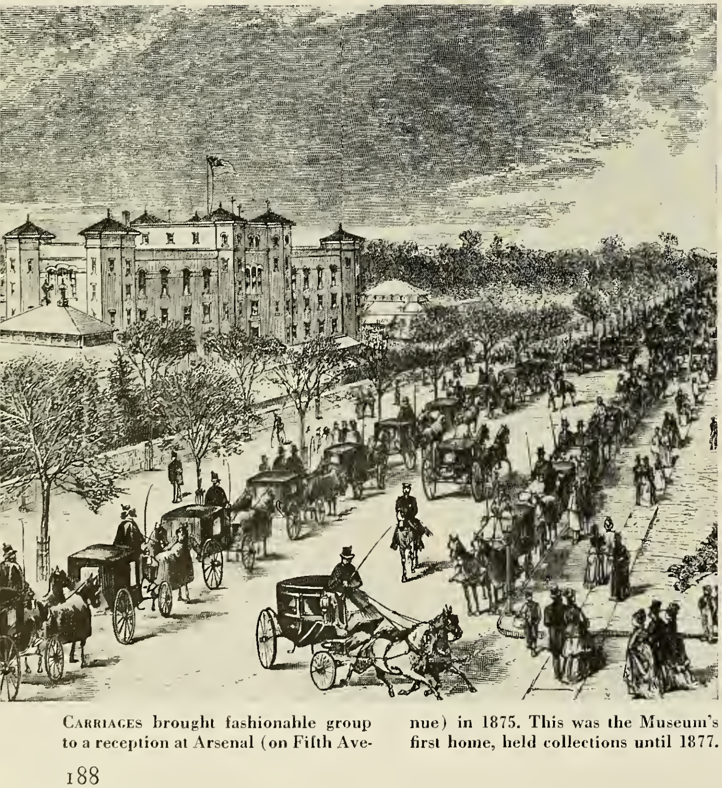
Plans were grandiose

The first plan for the Museum was made by Calvert Vaux. It was to be a splendid castle in what was then a wilderness. Only shanties, and two or three modest houses, were in the area. Bloomingdale Road (now Broadway) had not been improved this far north; farms, swamps and herds of goats were features of the landscape. Harlem was a tiny settlement to the north and daily stagecoaches were the only transportation.

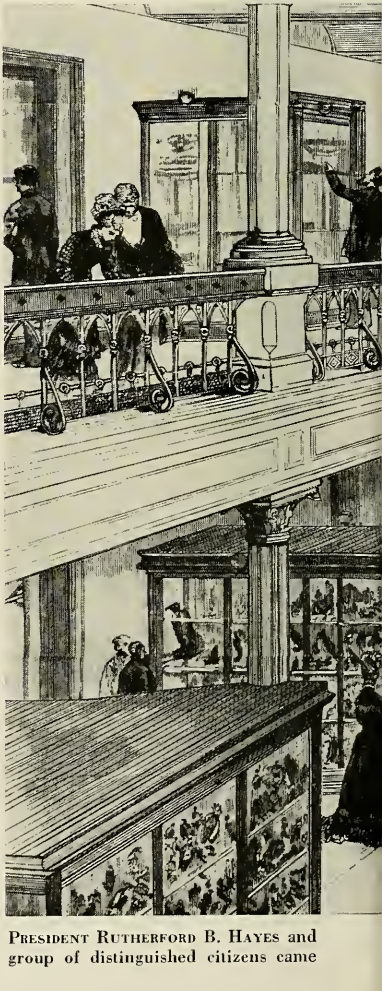
Eighth Avenue, now Central Park West, was almost unsettled. Central Park, itself—purchased by the City in 1853 and designed by Calvert Vaux



Museum's original plan appeared in *Harper's Weekly* in 1897. The central tower and full quadrangle have not been built: Planetarium was later concept.



Carriages brought fashionable group to a reception at Arsenal (on Fifth Avenue) in 1875. This was the Museum's first home, held collections until 1877.

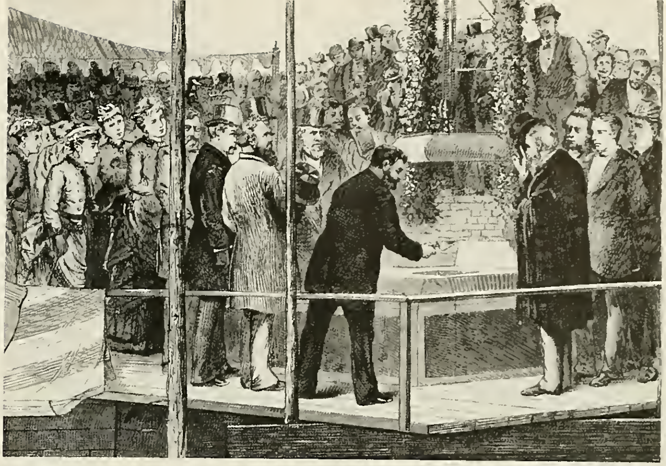


President Rutherford B. Hayes and group of distinguished citizens came

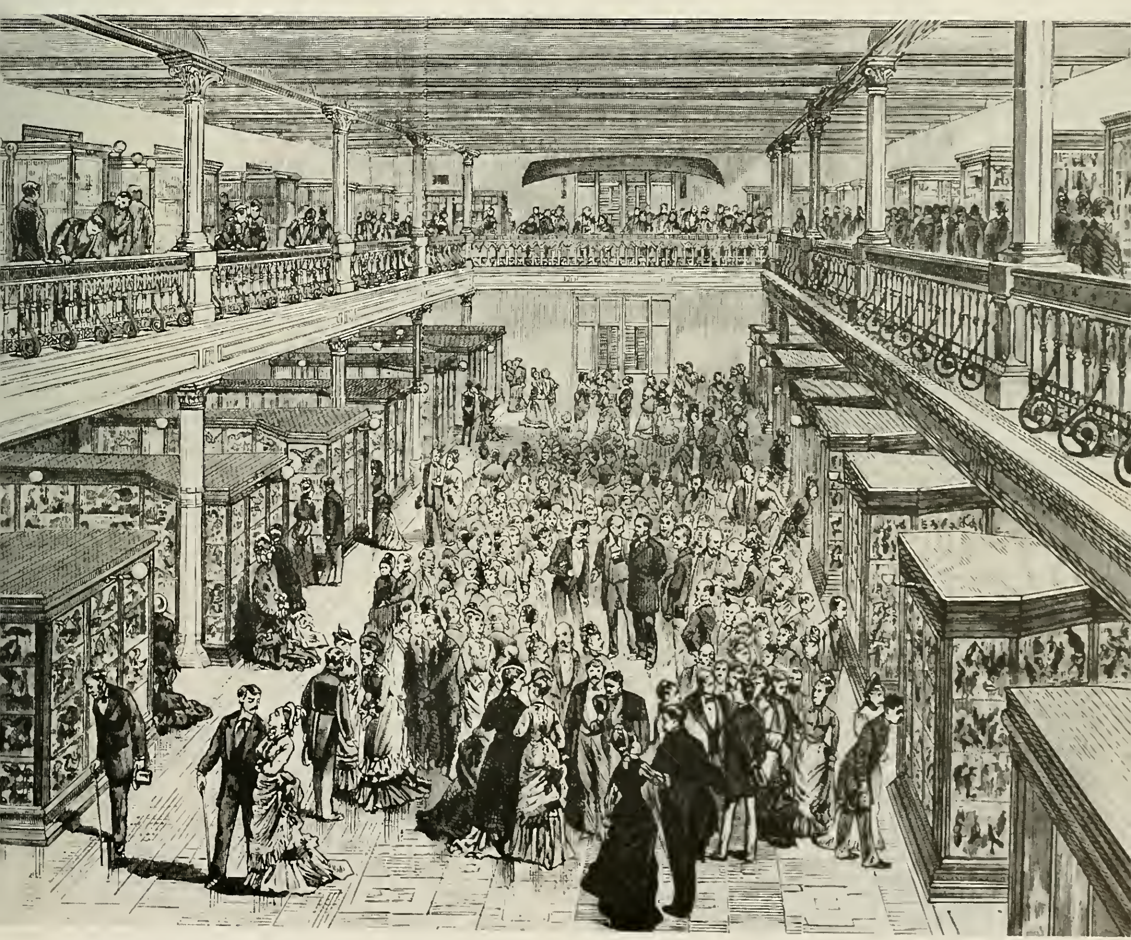
but the start was slow

and Frederick Law Olmsted—had been started in 1856, but was far from completed when construction of the Museum's initial unit was begun.

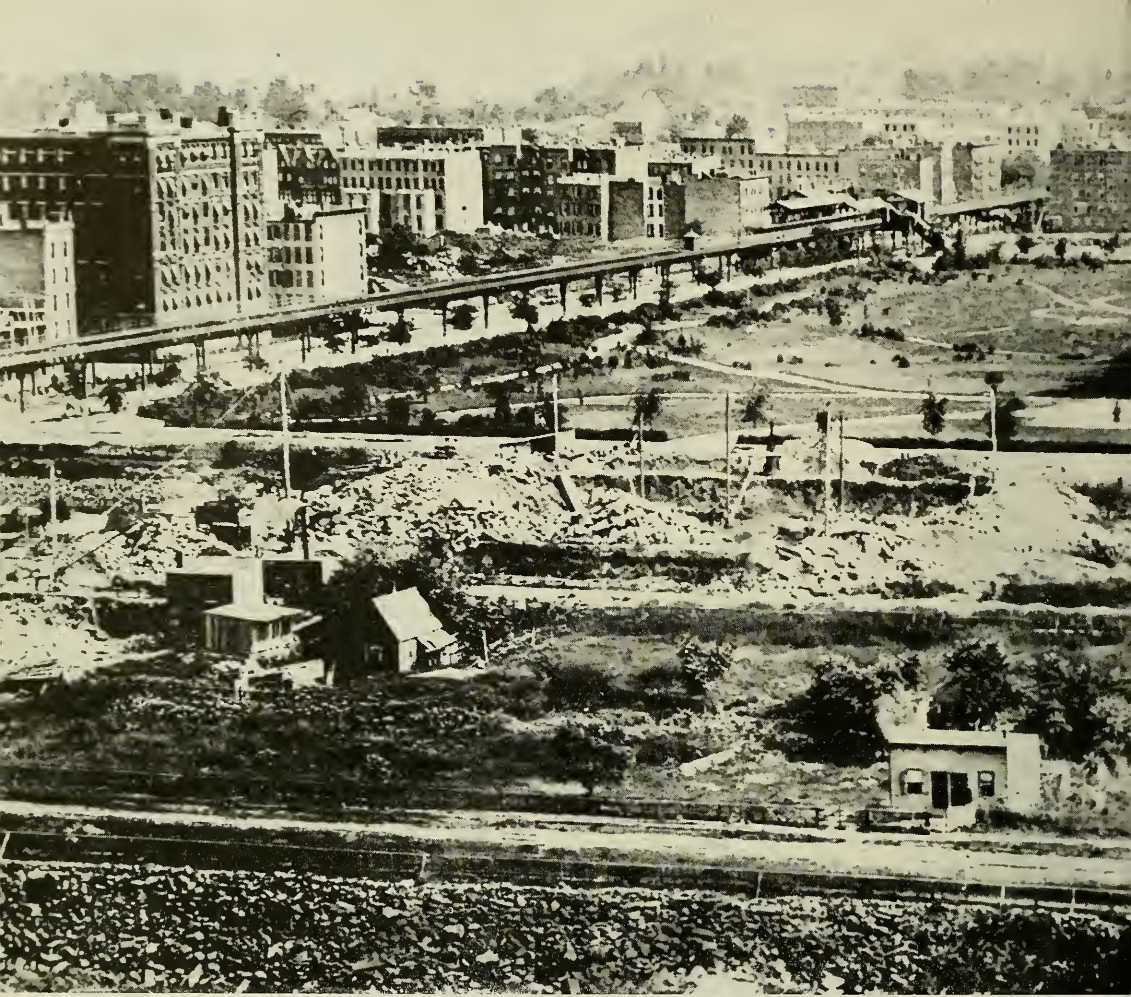
Such was New York City's West Side when the Museum was new. As it grew, the Museum grew with it. By 1892, its second unit was finished. This contained three large exhibition halls, a lecture room, six smaller halls and the library. The latter had actually come into being in 1870, built from collections donated by public-minded citizens who realized such a library's value. Today, it contains one hundred and forty thousand volumes.



Cornerstone for Museum's first unit was set by President Grant, *above*, in June, 1874. In it were newspapers and records, but location is now unknown.



to opening ceremonies, December, 1877. Note overcrowded cases and the scant attention paid them. This was a gay affair, with speeches lauding Museum. Engraving is from *Frank Leslie's Illustrated Newspaper*, January 5, 1878.



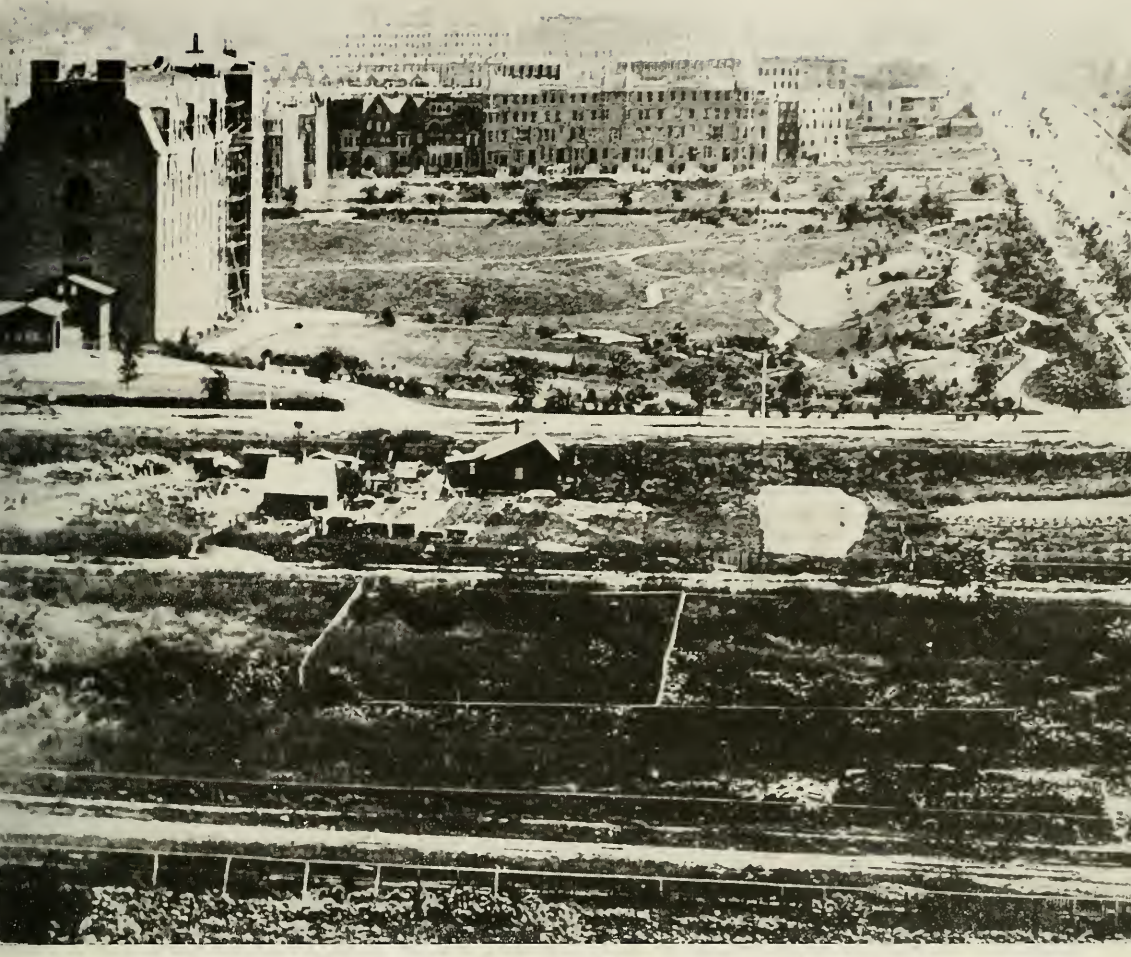
First unit of museum, *center,* off Seventy-seventh Street, was in midst of disorder in 1887. Apartment construction was booming; the Columbus Avenue elevated, *left,* had only recently been extended from its Fifty-ninth Street terminus.

A squatter's shack stood near Columbus and Seventy-ninth about 1893. "El" is behind, Museum in background, *right.*

Once begun, growth was steady

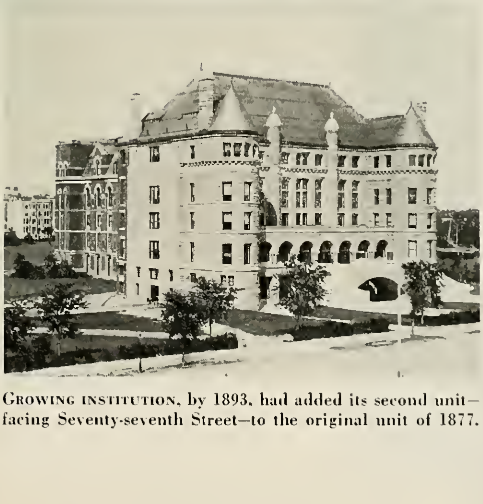
In the generation following construction of the first unit, The American Museum multiplied its size fourfold. Exhibited within was the Museum's first major acquisition — a great collection of mammals, birds, reptiles and amphibians purchased from Prince Maximilian of Weid-Neuwied in 1869. For study purposes, the renowned fossil collection of Professor James Hall had been obtained in 1873. P. T. Barnum had donated an iguana and "one Human Hand."

Museum expeditions had gone to the western United States, to Mexico, and across the Pacific. By 1900, such distinguished scientists as Henry Fairfield Osborn, Barnum Brown, Franz Boas and William K. Gregory were on the staff. Albert Bickmore's public instruction program was rapidly extending outward into the public schools, and classes at the Museum were steadily growing larger.

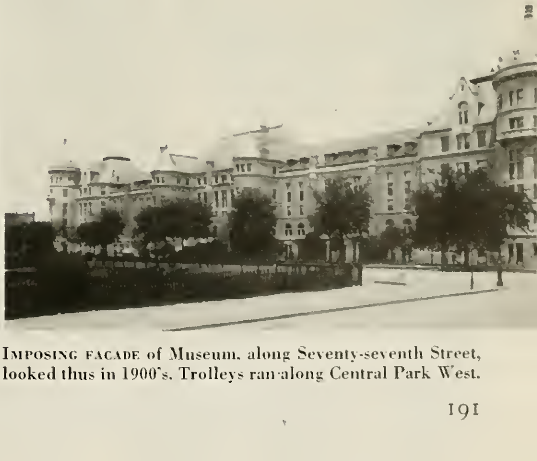


Central Park is barely seen, *far right*. The "El" made the Museum much more accessible; attendance taxed the staff.

Manhattan Square, the Museum's 14-acre locale, originally was considered as a possible spot for a zoological garden.



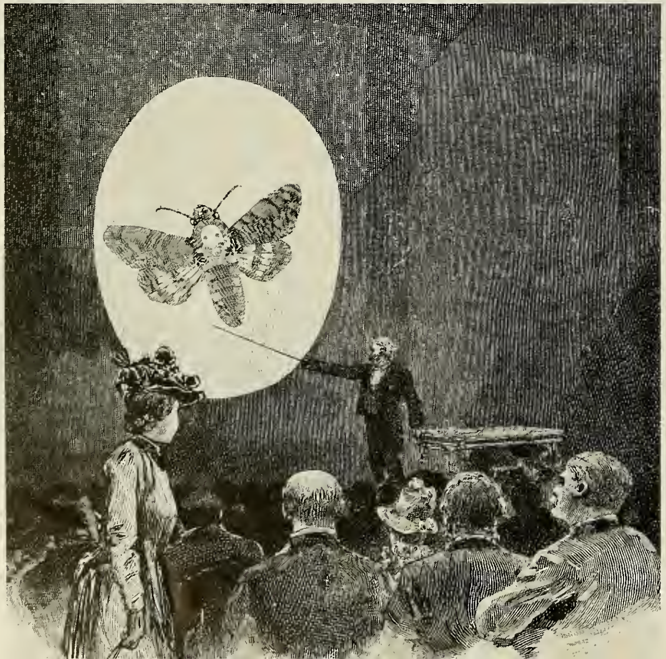
Growing institution, by 1893, had added its second unit—facing Seventy-seventh Street—to the original unit of 1877.



Imposing facade of Museum, along Seventy-seventh Street, looked thus in 1900's. Trolleys ran along Central Park West.

Professor Albert S. Bickmore was Museum's founder and first director (with title of Superintendent). He is seen here in his study at Museum.

The museum of today, *above,* may be compared with original plan on p. 188. Open area, at *top,* was named Theodore Roosevelt Park in ceremony last year.



Bickmore initiated public instruction in 1880 by giving lectures illustrated with lantern slides. Here he uses the method in dissertation on Lepidoptera.

Here, imagination was loosed of fetters and has never ceased to grow

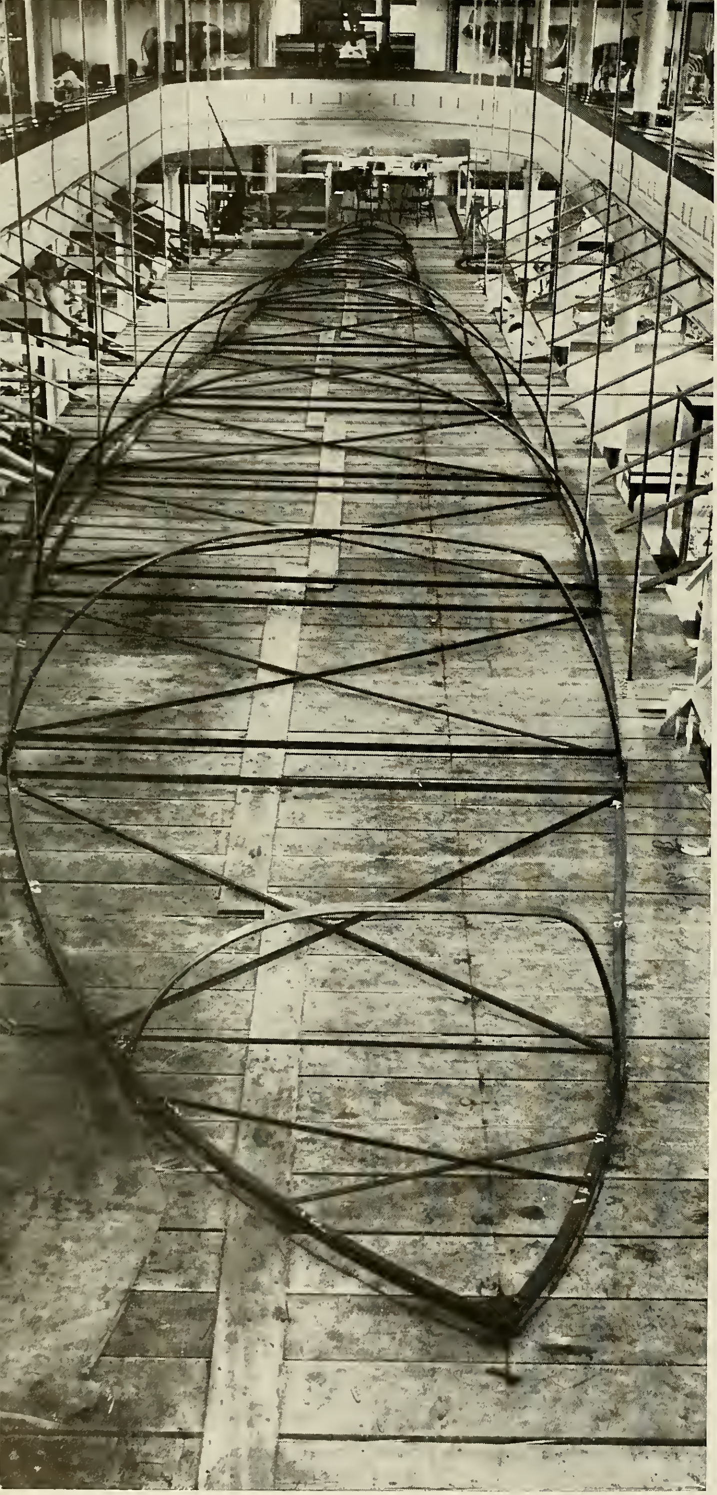
Superintendent Bickmore studied under Louis Agassiz at Harvard's Museum of Comparative Zoology. Later, he was to travel widely in Asia and Siberia. During these travels he said "I carried with me everywhere two things, a Bible and a sketch of a plan for a museum in New York."

Upon his return from Siberia, he decided the time was ripe to rally the support he needed and build his museum. He called upon William E. Dodge, Jr., the wealthy amateur conchologist, and was given a letter to the senior Theodore Roosevelt. Roosevelt, with others, took the lead in bringing Bickmore's project to reality.

From the Museum's inception, Bickmore pioneered. The teaching of natural history had not been thought of much importance before; now it sprang into demand at an astonishing rate. Bickmore began the educational program in 1880 — with a lantern-slide lecture on coral islands (the Museum's Department of Public Instruction now reaches over nine million people each year). Bickmore's visual method was new, and he used it to the full, beginning an endeavor that has never ceased to expand. From bringing living knowledge to teachers, his first goal, he went on to include "artisans, mechanics and other citizens." Finally, came direct demonstrations for school children.

Bickmore and his staff fired the public's imagination with exhibits and lectures. By the turn of the century, rising interest brought a million visitors to the Museum yearly.

Elephant's skin is cleaned, *above*, in preparation for mounting. Now one of the group in Akeley Memorial African Hall, this specimen (taken during 1929 expedition) was not mounted until 1935.



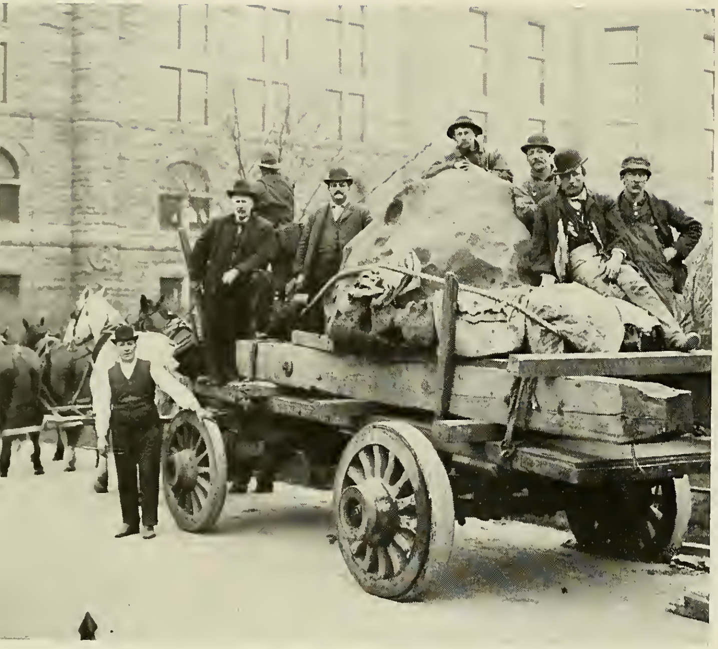
Framework for replica of a blue whale was built by Roy Chapman Andrews and others in 1906. In life, this mammal was 76 feet long and weighed 63 tons. Model still draws admiring spectators.

The Art of Exhibition

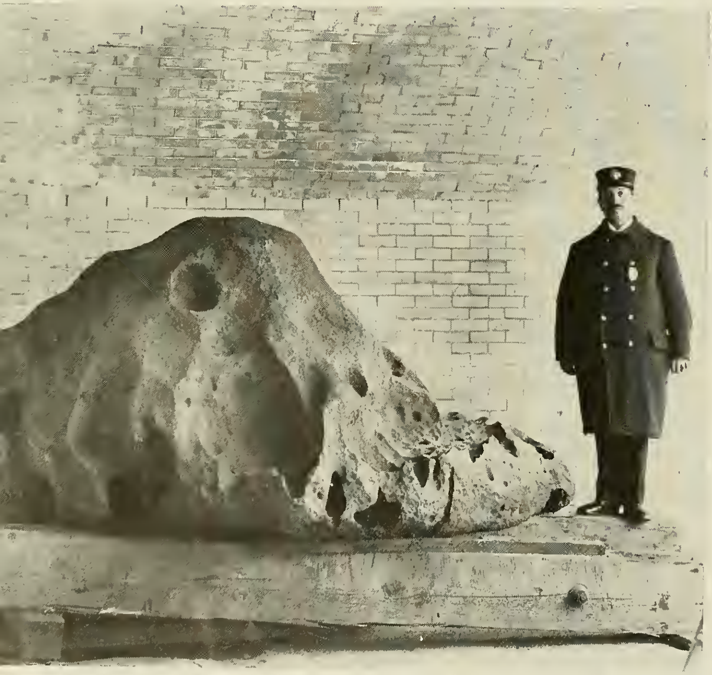
New standards of realism helped solve the problem of re-creating nature

When an art museum wants a new exhibit, it buys things in finished form and hangs them on its walls. When a natural history museum wants one, it often must build it—from a mass of material and evidence brought together by painstaking search and research. An animal, for example, must be skinned and its skin prepared. Photographs and measurements must be used to determine position and structure. Muscle forms must be built accurately of clay, a plaster mold and shell made, and the skin pulled over the adhesive-coated shell, as a wet glove is drawn on.

This determination to present the subject as it appeared in life is followed in many places today. But in the Museum's early days, it was a new idea — bold and expensive. One of many concepts pioneered by the Museum, it opened new avenues to the creation of exhibits that allowed the public to see nature untouched by man.



Willamette meteorite came to Museum on a wagon in 1906. The largest found in U.S. up to that time, the 15.6 ton object now stands in Planetarium.



A **guard posed** by Willamette, *above*, to show its size—ten feet in length, six and one half feet high. Meteorite had been discovered near Oregon City, Oregon.

At first, the Museum

A score of years before Mohammed was born, in A.D. 570, a tree in California was reaching for the sky. Anglo-Saxons were still crossing the channel from the continent to England. Charlemagne's time lay over two centuries in the future: the Battle of Hastings was half a millennium away. But in a California mountain valley, what later came to be known as the Mark Twain Tree, *right*, was a sapling among the giant sequoias.

When cut, in 1891, the Mark Twain Tree was three hundred thirty-one feet tall, ninety feet in circumference at the base, and without limbs for its first two hundred feet above the ground. A cross section, weighing nine tons, was brought to The American Museum in pie-shaped segments in 1912 and reassembled there.

Meteorites are our only available specimens from beyond the earth. No one can say for certain how they were formed. Yet their age can be estimated by their content of radioactive elements and they contain no unknown substances. Some are made up of iron and nickel alloys and some are silicates. It is generally believed that they originated in the belt of asteroids—a zone of fragments, perhaps of an ancient planet — rounding the sun between Mars and Jupiter. There are some 50,000 asteroids, the biggest of which —Ceres—is some five hundred miles in diameter. The largest known meteorite, which lies where it fell in Africa, weighs about sixty tons. We can measure, weigh, analyze and describe these wanderers from out of the cosmos but, in truth, we know little about them.

It is, of course, fundamentally a mechanical problem to collect and exhibit such things as stone heads, giant trees and meteorites. But most of natural history presents more difficult problems. What can be done with a tropical rainstorm, a stretch of rocky beach, a bird song, or the colors of an autumn forest? How can the nature of a creature, too tiny to be clearly seen, be demonstrated—a millepede, a nematode one-eighth of an inch long, microscopic protozoa, a thrip?

To show virgin nature, as it really is, new methods had to be devised, and were. The sounds of a rainstorm or a bird call can be recorded on tape, and played to the viewer of a scene painstakingly constructed to

sought unique things

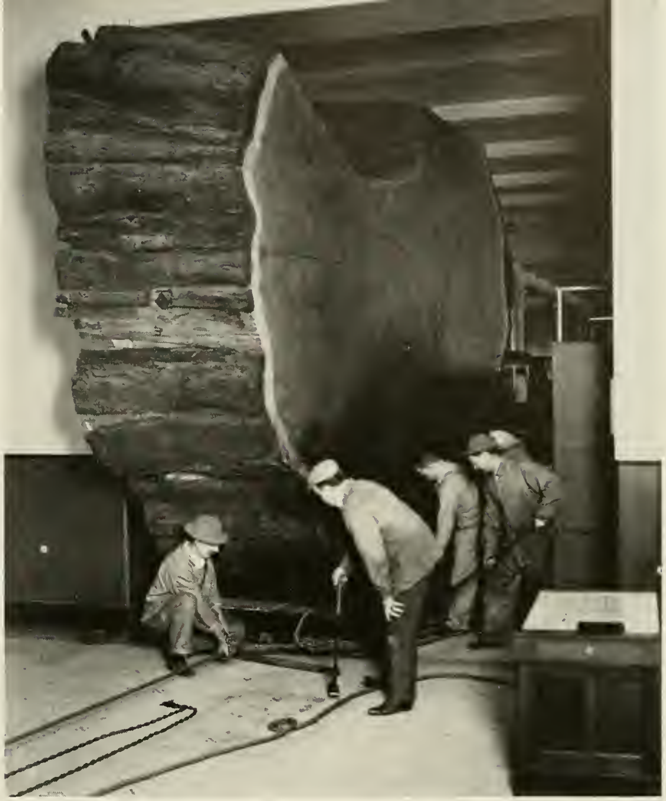
show how a rain forest looks and how man can adapt himself to life within it. In one Museum hall, the visitor may hear the sound of rain and the cries and calls of monkeys, parrots, toucans, toads and insects—to complete a picture of life in the Peruvian Montaña. Beaches, swamps, and the magnificence of an autumn forest can be, and have been, reproduced in detail in other Museum halls.

What of the flea, the termite and the ant? Since they are too small to be seen clearly, they must be enlarged in models. The Insect and Spider Hall of The American Museum of Natural History is the largest and most complete exhibition of its kind in the country. Here are models of fleas, houseflies and a myriad other insects —enlarged up to seventy-four diameters—showing their stages of development, the differences between male and female, and the workings of their ingenious physiology.

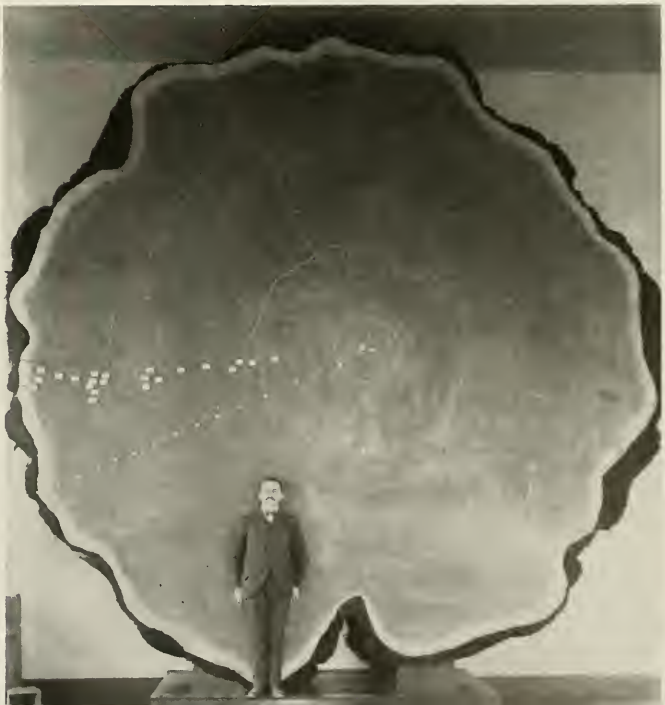
It is not enough merely to stuff a tanned skin. Muscle structure varies with the position and activity of the animal. Carl Akeley, sculptor, inventor, explorer and taxidermist, early recognized that muscle structure under the skin must also be correct. As did S. H. Chubb, he determined to find what things should actually look like (*see p. 198*). Under Akeley's leadership, a whole new philosophy of exhibition was born, in which Museum preparators presented each animal in some typical attitude — fighting, resting, stalking game. They came alive in the Museum halls — leopards from India, beaver from the Midwest, bears from Alaska, elephants from Africa. This realistic taxidermy is generally accepted museum practice today, but— in the beginning—it was an entirely new frontier.

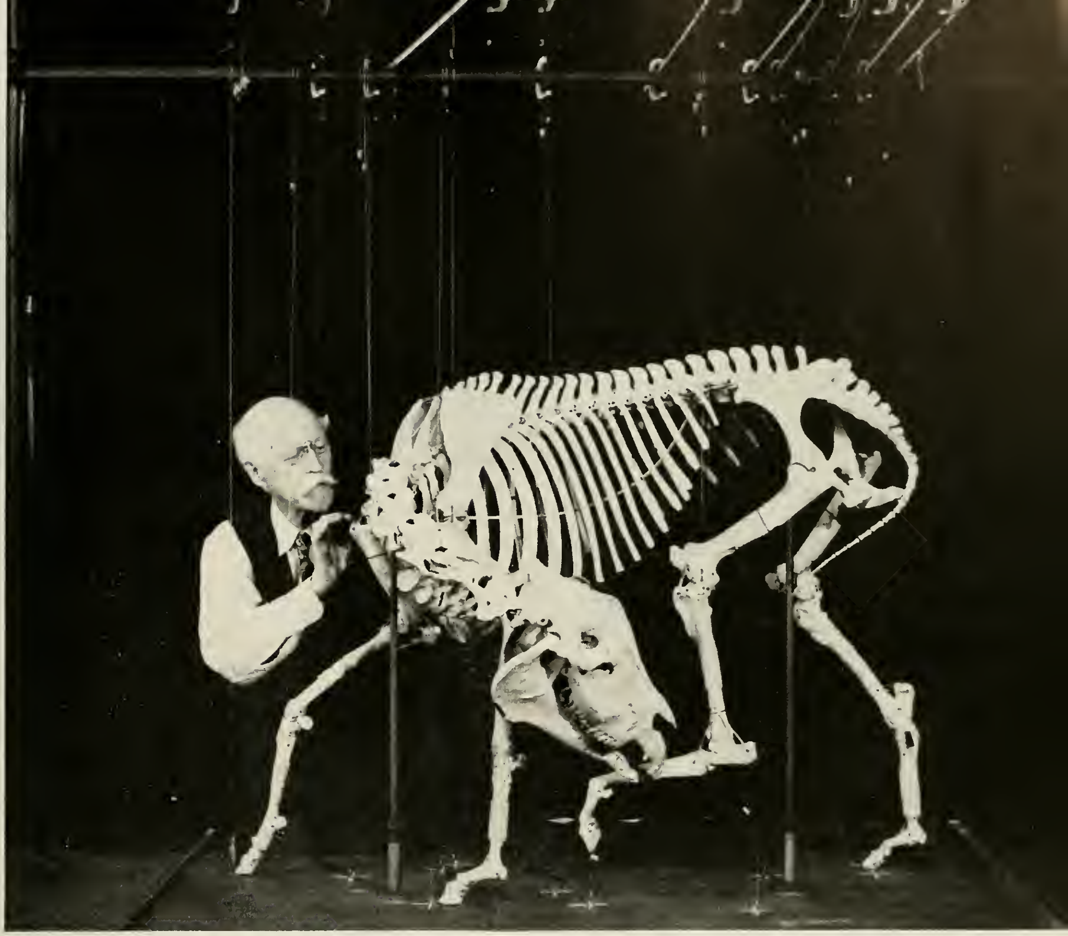
A realistic habitat group is the perfect mating of science and art—which the Greeks regarded as the true purpose of a museum. The painted backgrounds of habitat groups are great examples of purposeful art. The blending of foreground with the background often defies detection. Prehistoric animals, too, known only from their skeletal remains, have been reproduced as in life by the co-operative endeavors of scientific research and artistic skill.

For a look at scientist and artist at work, see the next four pages.



A GIANT SEQUOIA SECTION, 1,341 years old, was brought to Museum in chunks, *above*, in 1912. It is on exhibit, still, in the Hall of North American Forests.





Chubb's rig, *above,* suspended all parts of skeleton (here, a donkey), was adjustable to obtain the exact action desired.

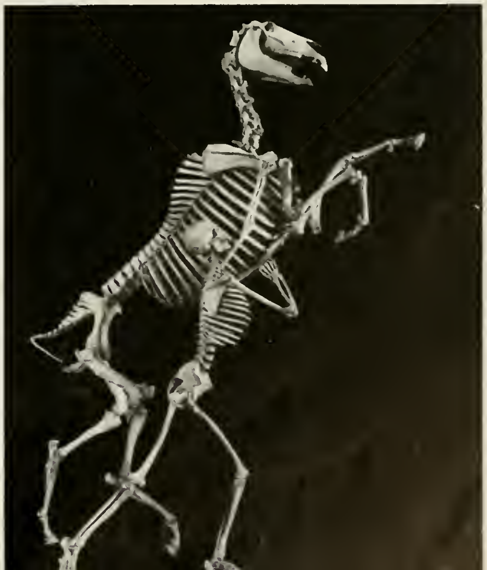
Famous example of Chubb's work is this rearing horse and man, *below.* Pair has almost become the Museum's emblem.

The knack of achieving realism

The Museum's eminent comparative anatomist, Samuel Harmstead Chubb, stopped at nothing to assure that animals were mounted in natural positions. His studies were begun in 1907, and led directly to his invention of the elaborate scaffold, shown above, that made unlimited re-positioning possible until precisely the correct posture was reached and then made rigid for exhibit.

These things—scientific observation and interpretation, combined with the artist's eye for form and color—are the combination on which the Museum's program of exhibition is based. The work goes on with painstaking exactness, year in and year out, in behind-the-scenes laboratories and workshops within the Museum. For—as with an iceberg—only a tenth of the Museum's whole is visible to the casual observer strolling through its halls.

Dangling outside the Museum, *left,* Chubb made pictures of a trotting horse, used in the study of natural positions.



Painter Bruce Horsfall and his wife work on background for bird exhibit in 1907. Bird-hall exhibits were first to use habitat group approach in display.

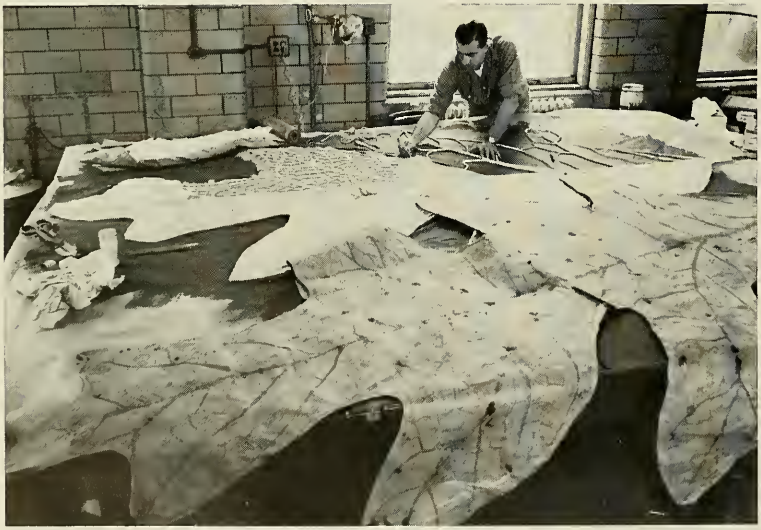
Artist F. L. Jaques completes a scene for Whitney Memorial Hall of Birds.

A historical tradition in art was the key to imitating nature

The idea of reproducing nature in art is not new, and few artists have surpassed the frescoes at Pompeii in freshness and grace, the seventeenth-century Dutch genre paintings in detail or John Constable for his rendering of light. Museum background painters have drawn on all these traditions and others, but their problems are unique. For one thing, background painting must merge with the three-dimensional objects in the foreground. For another, as the backgrounds of habitat groups came to be curved rather than flat, the painter faced the problem of making everything in the background seem properly shaped when viewed from any point in the spectator's arc, which extends some fifteen or twenty feet.

At first, in the Museum, there was little concern with such problems of aesthetics or naturalness. As the preparator and taxidermist James L. Clark has said, animals were then "mounted stiffly erect, often with no hint of their natural attitudes, and certainly with no appropriate background surroundings." The already mentioned Mrs. Mogridge—two of whose exhibits, of passenger pigeons and Labrador ducks, are still on view—was the first to break with this habit; and with the encouragement of Curator Frank M. Chapman, the birds continued to fly ahead.

A bird hall, opened about 1900 and now closed, was the first to present habitat groups as we know them today.



Gigantic scale of models is seen in a three-dimensional exhibit in recently opened Hall of North American Forests. Oak leaf made of cotton and wax, at the left, is twelve feet long. Resting on it, *at right*, are three-foot daddy-long-legs,

ALASKAN GLACIER is painted by Belmore Browne, in 1946, as background for group in Hall of North American Mammals.

Some of these exhibits, although they had painted backgrounds, were walled or glassed-in at the sides; but in most of them, the crucial step was taken: curved backgrounds gave panoramas of the birds' natural habitats.

Today's background artists, however, face a multitude of problems which did not exist for the technique's first pioneers. It was Akeley's technique of mounting animals with their natural musculature and in postures of action that enormously complicated the artist's task of making the exhibit a unified whole. Yet, the background artists have been equal to diverse challenges, and their roster is a distinguished one, from Bruce Horsfall and Louis Agassiz Fuertes through William R. Leigh to Belmore Browne and James Perry Wilson. Their successors today continue an authentic, and authentically American, tradition.

five-and-a-half foot millepede made from air hose, and acorn two feet wide. Magnification is twenty-four times life size.

ARTIST-IN-FIELD Matthew Kalmenoff, *above*, sketches scene for new forest exhibit. In Museum, *below*, he completes work.

Research Is The Foundation

The Museum's scientists provide a basis for its accomplishments

THE VIIth International Zoological Congress met in Boston in August. 1907. After adjournment. many of the delegates came to The American Museum of Natural History for a visit. The picture on the preceding pages. taken that year, shows some of the greatest natural scientists then alive, including many staff members of the Museum. A key to the identities of some of the latter appears at the bottom of this page.

The visitors, of course, had been attracted partly by the exhibits, which were already recognized as new in concept and execution; but more than this. the research done at the Museum commanded respect. In the world of science, research is the process that is fundamental to any institution's achievement of prestige.

RESEARCH is one of the means by which man struggles toward mastery of himself and his world. It is far more than the mere observation of facts. It is also application of these facts to the development of new concepts and to the correction (or refinement) of concepts previously held valid. This can go a step further, and practical application is made of research's discoveries — in educational methods, inventions and solutions to a hundred everyday problems.

To be productive, research workers need ideas, techniques and equipment (including a library). In The American Museum, all are available. And, whenever possible, the Museum sends out field parties to acquire the information and specimens needed to further research programs. In many research problems, consultation with workers in related fields provides new insight into work at hand. The various fields of science at the Museum frequently overlap in this way.

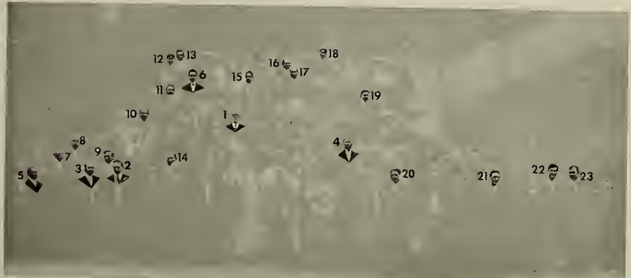
CONSIDER an example. The extinction of the dinosaurs and some other major groups of early reptiles at the end of the Mesozoic era has long posed a problem. Why did they die out? The answer to this question — of interest to the paleontologists — is complex. Many causes may be involved. One possible approach to the problem is the matter of temperature regulations in the reptiles that survive today, a field of study for the biologist.

Today, the largest reptiles live in tropical areas, where the climate is neither too hot nor too cold. Although these creatures are called "cold blooded," because they depend on the sun for their body heat. many active lizards manage to maintain a body temperature warmer than our own. The desert iguana of our Southwest, for example. habitually maintains a mean body temperature of 107°F. On the other hand, the large green iguana of the American tropics usually has a temperature of about 90°. Because of its size, the green iguana not only needs more time to bask, but more time to dissipate excess heat. Thus, it is able to control its body temperature with much less precision than can the smaller lizards, which are able to take advantage of shorter periods of sunlight.

Armed with these facts, we can speculate that dinosaurs, too, were in large part dependent on the sun for their body heat. Now, assume that great temperature changes occurred — changes that caused the temperature of the dinosaurs to drop even as little as four degrees below the point at which they could remain active enough to search for food. Similarly, sharp *rises* in temperature could have drastically affected the great beasts.

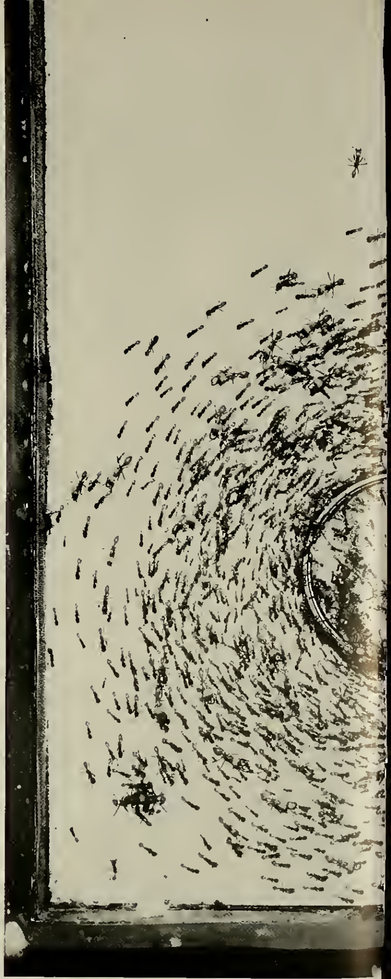
While we have no way of knowing, therefore, to what extent temperature changes brought about the extinction of all the many kinds of dinosaurs, contemporary studies of their remote relatives afford some insight into the role temperature change *may* have played in this ancient event.

Thus, the Museum's research programs continuously overlap and supplement each other. The Museum's three major fields of research are biology, geology and paleontology, and anthropology, each with its several branches. And each field depends on every other. Fossil corals — and fossil dinosaurs — cannot be truly understood without study of their living relatives. Nor, conversely, could the modern dog — or dogfish — be completely appreciated if the long lines of their ancestry were not known.

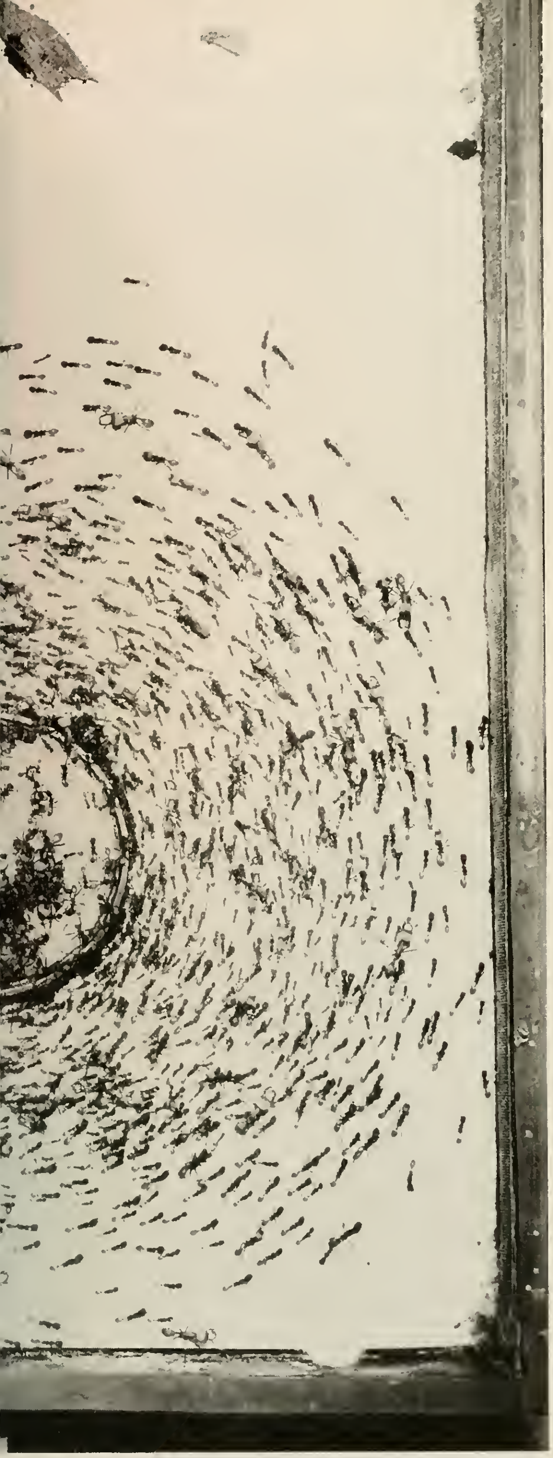


MUSEUM STAFF, in 1907, stood on 77th Street steps with delegates to the International Zoological Congress for the remarkable group portrait on the preceding pages. Among the more than fifty staffers were six higwigs of past and future: (1) Founder Bickmore; (2) Henry Fairfield Osborn, who became President the next year; (3) Hermon Bumpus, then the Director; (4) Frederick Lucas; (5) George Sherwood; and (6) Roy Chapman Andrews, each of whom was to become Director of the Museum. Others identified in this key are: (7) S. Harmstead Chubb; (8) B. Eric Dahlgren, invertebrate zoologist; (9) Walter Granger, field paleontologist; (10) Frank Chapman, ornithologist; (11) William Beutenmüller, entomologist; (12) James Chapin, ornithologist; (13) James Clark, sculptor; (14) Joel Asaph Allen, mammalogist; (15) William Morton Wheeler, conchologist; (16) Anthony Woodward, cartographer; (17) Barnum Brown, vertebrate paleontologist; (18) Roy Waldo Miner, invertebrate zoologist; (19) Bashford Dean, ichthyologist; (20) Ralph W. Tower, physiologist; (21) William D. Matthew, vertebrate paleontologist; (22) Robert Cushman Murphy, assistant; (23) John T. Nichols, assistant.

FOSSIL STING RAY, in the paleontological study collection at the Museum, lived in Wyoming lake sixty million years ago.

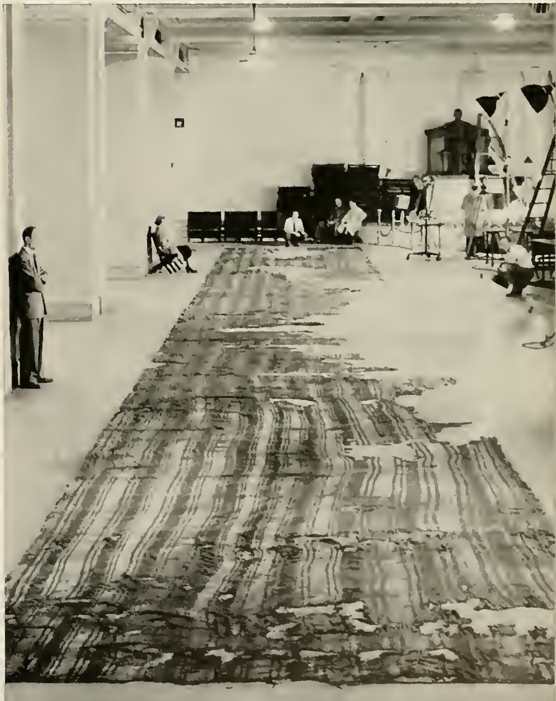


CANAL ZONE army ants march in circles in laboratory test devised by a Museum scientist working at Barro Colorado.

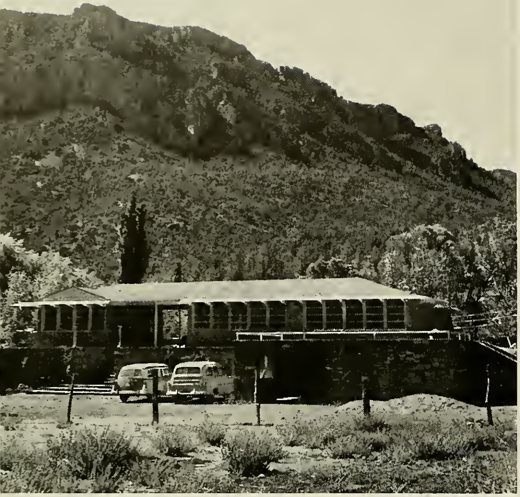


Biological studies—both taxonomic and behavioral—make up one of the Museum's three major divisions of research.

Longest specimen of Peruvian cloth yet to be discovered, *below*, is taken off mummy, *above*, by Museum archeologists.



Researches are broken into



Southwestern Research Station, in Arizona, has a wide range of desert and mountain environments for experiments.

Sciences are not only interlocked, as shown on the previous pages; they are also divided into many segments. For example, within The American Museum, the biological sciences, alone, have been divided into six separate departments: the study of mammals, birds, amphibians and reptiles, fishes and aquatic biology, insects and spiders, and the general field of animal behavior. Geology and paleontology are in a single department, yet the interests of its scientists range from mineralogy to the study of fossil invertebrates, and a separate department is devoted to the field of micropaleontology. In the latter, some researchers specialize wholly in Foraminifera — organisms useful in identifying strata from drill cores, and therefore helpful in the hunt for oil. [The Museum publishes a quarterly, *Micropaleontology*, dealing in part with these creatures, often less than one one-hundredth of an inch in size.]

The study of insects and spiders affords another example. Because of wide variation, specialization in study is a necessity. The beetles (the Museum is now studying the world's largest, four inches in length) function quite differently from such social insects as ants and bees. Spiders (which are *not* insects) exist in varieties too numerous to touch upon, but each variety is a fair subject for research.

It could well be said that, in the natural sciences, the things to be determined are infinite, and that each discovery brings new problems. The scientific staff of The American Museum pursues such discoveries and wrestles with such problems. Through the Museum's scientific publications, they—and their colleagues in other institutions—tell the world what they have found.

Not all this research is done in New York City. Field investigations are made in many parts of the world, collections returned for study and exhibit and observations published on the findings. Nor is such research all.

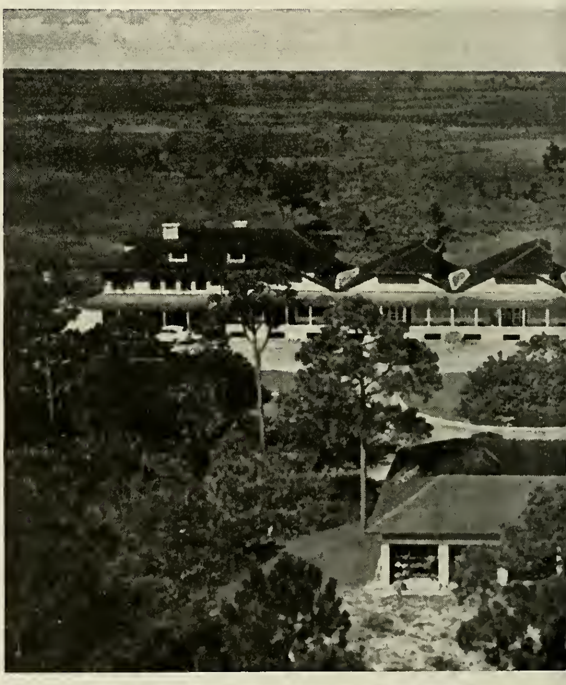
Museum scientists already work regularly at the three field stations pictured here. The Archbold Biological Station was established in 1941, the Lerner Marine Laboratory in 1947 and the Southwestern Research Station in 1955.

Established by Richard Archbold, the first of these three is located in south central Florida—in an area of cypress swamps, sand scrub, high pinelands, flatwoods, live oaks, open marshes, ponds and lakes. Probably no other region of Florida presents such variety for biological research. Alligators haunt nearby lakes and streams and there is easy access to herons, egrets and ibis, dragonflies, butterflies and a blending of temperate and tropical fauna. Equipped with excellent laboratories, workshops, cages for large and small animals, photographic darkroom, boats and diving equipment, its facilities are open to all qualified investigators approved by the Station's advisory board.

Research on animals carried on here has ranged from insects to toads, and much botanical work has also been done. While fresh-water and inland life are most accessible, the station is conveniently close to both Florida coasts.

The Lerner Marine Laboratory is at Bimini, in the Bahamas, some sixty miles east of Miami. Bimini is a low island of coral sands, on or near which most Caribbean and West Indian forms of life exist.

As in the case of the Archbold Station, its facilities are provided to visiting scientists, who have carried on work in geology, animal behavior, marine ecology, paleoecology, oceanography and endocrinology. In addition to the Mu-



Archbold Biological Station, in Florida, lies in an area of cypress swamps, palmetto flats and subtropical climate.

a myriad of specializations

seum's staff. scientists have gone there from the Sorbonne, Harvard. Yale. Cornell, Columbia. the New York Zoological Society. the Geological Survey of Canada, and more than a dozen other distinguished institutions.

The shallow waters of the Great Bahama Bank are the home of an extraordinary variety of fishes and marine invertebrates. The opportunities for studies in marine biology—and botany and entomology as well—are broad.

The hurricane season makes work impracticable from September through the end of November each year, and the laboratory is then closed. During the remaining nine months of the year. however. the Lerner Laboratory is a busy place: last year, more than forty visiting scientists used the facilities of the Laboratory.

Lerner Marine Laboratory, on Bimini, surrounded by life of tropic waters, is famed for marine biological research.

The third major Museum field facility is the Southwestern Research Station, on the eastern slope of the Chiricahua Mountains in Arizona, near the New Mexico border. Its altitude is 5,400 feet, and the area is convenient to both desert and higher mountain zones.

Oak. juniper. pine. cottonwood and willow surround the station, and the available fauna ranges from that of north central Mexico to that of the Rocky Mountains. There is probably no area in the United States with a more varied natural history. including at least nineteen species of bats—many of them to be found in nearby Crystal Cave.

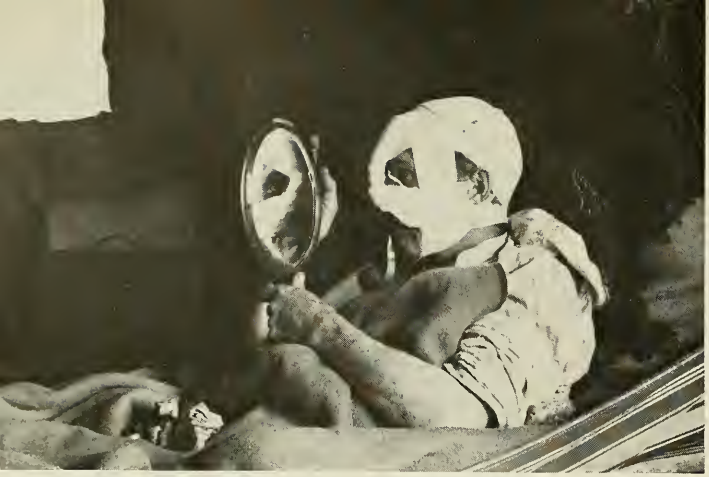
Geologically, the Chiricahua Mountains offer formations from pre-Cambrian to Quaternary. all of which may be found within ten miles of the Station. There are also many volcanic rocks—basalt. tuff. and the like—of Tertiary and Cretaceous age. For the paleontologist. a rich fossil fauna is available in an Upper Mississippian formation.

There are also archeological remains in the vicinity. One stage of the "Cochise Culture," a pre-pottery culture in the Southwest. has been identified in middens and hearths in the foothills of the Chiricahuas. This "Chiricahua stage" dates from 8000 to 3000 B.C. As with the other field stations. visiting scientists come from anywhere in the world. Over three hundred have worked here thus far.

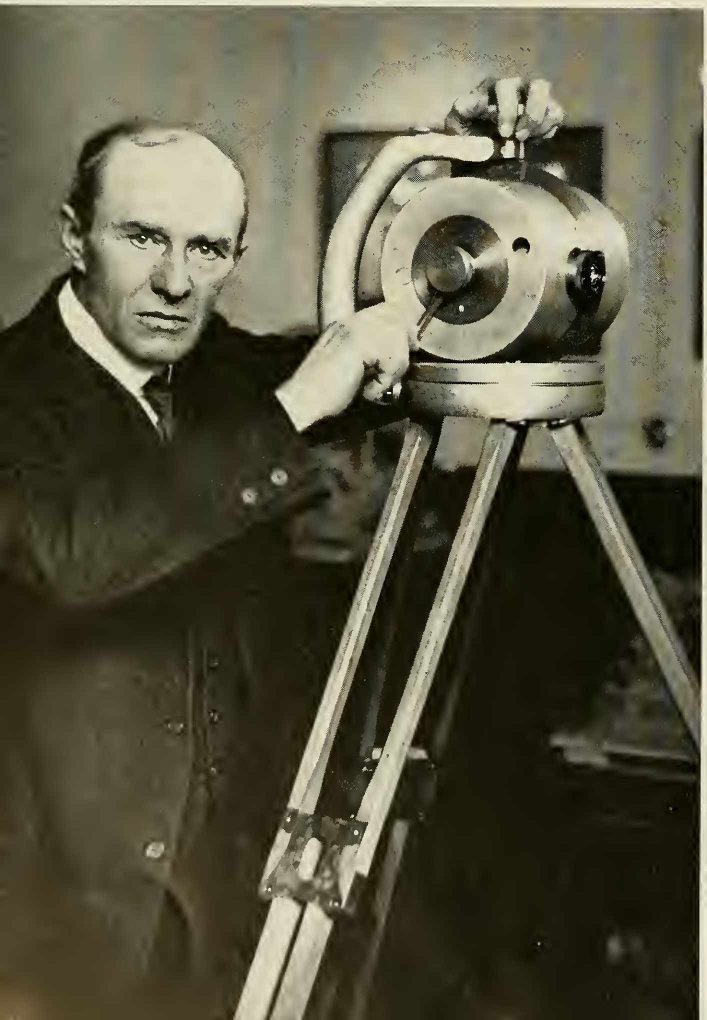
Among other animals, such diverse creatures as alligators, pelicans and silkworms have become subjects of study here.

Each of these field stations is strategically located. has a completely different surrounding area, and offers its own opportunities for field research in natural history. The purpose served by these facilities is useful and simple: to provide a locale where specific problems may be attacked at modest expense under ideal laboratory conditions. Each field station is a happy compromise between work in the city-bound Museum and the unattractive alternative of hasty field work—which often affords insufficient chances to make prolonged studies of materials *in situ*. The wide range of projects carried on in these field stations—including many that originated outside the Museum staff—has proved the stations' value to science.

Diverse as the locations of today's field stations are, they are too few in number to take full advantage of the potential implicit in the field station method. These three—and the newly established Kalbfleisch Field Station on Long Island—are, in a way. pilot projects. In the world. today, there are more than three hundred field stations. under various sponsorships. yet there remain unexploited areas that would serve the purposes of natural history equally well. or perhaps better. But further expansion of the Museum's field station program must wait a later time.



MAULED in encounter with elephant in 1909, Carl Akeley, *above*, was badly injured. He is shown, *below*, in 1916, with panoramic ciné camera that he invented.



Distant

The explorers bring

THE MUSEUM'S first official expedition, in 1887, went to the Bad Lands of Montana for bison. Thus began a record—it now totals almost a thousand—of exploring parties that have left the Museum in search of exhibit and research materials and information. The Museum's largest was the Third Asiatic Expedition, in 1923, led by Roy Chapman Andrews. With forty men, over a hundred camels, five cars and two trucks, he traversed 2,200 miles of hitherto unexplored wastes in the Gobi Desert. One of the Museum's best-known ventures, it returned with invaluable information and material, including the celebrated fossil dinosaur eggs, with which Dr. Andrews is shown below.

THERE were other expeditions almost as big—the Eastman-Pomeroy-Akeley, in Africa from 1925 to 1929, and the Jesup, on both coasts of the North Pacific from 1897 to 1902, are two. But most of the Museum's field parties have been much smaller. In many cases, one durable scientist has gone into the bush, alone, to search out birds, mammals, fossils or strata.

IN GOBI, in 1923, Roy Chapman Andrews takes picture of fossil dinosaur eggs.

Journeys

new knowledge home

The "Golden Age of Exploration," as it has been called, took place during the 1920's. This was the period of large, lengthy—and extremely productive—expeditions. The market crash of 1929 greatly curtailed grants of funds to the Museum, yet the 1930's saw the greatest *number* of field parties—over two hundred. In 1930 alone, thirty-five parties went out and that same year, the famous ornithologist Robert Cushman Murphy, in NATURAL HISTORY, wrote this epitaph for the Golden Age: ". . . the haphazard age of discovery is over, and exploration is no longer an end, but a means."

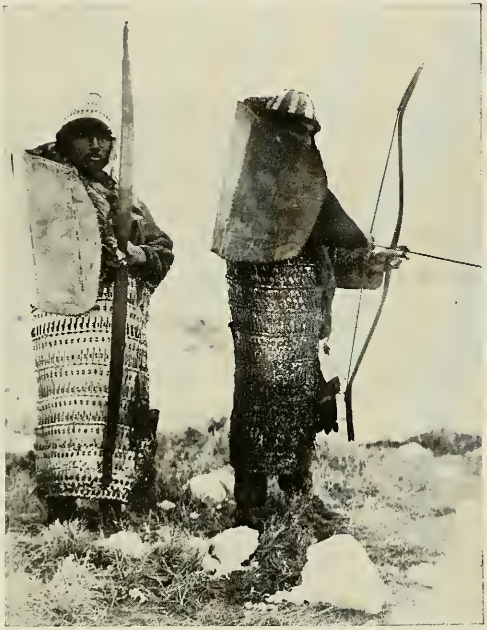
THE contributions of exploration to knowledge have been most impressive, and the methods developed for work in the field are hardly less important. Franz Boas' work on the Jesup North Pacific Expedition, for example, became a model for future ethnographic surveys. And on the level of field techniques, the motion picture camera was an ungainly tool until Carl Akeley invented a camera (*opposite*) that aimed as easily as a pistol and swiveled in any direction.

PAMIR SNOWS are background for James L. Clark and fallen *Ovis poli*, in 1926.

POSING WITH GORILLA, *above*, in 1929. W. K. Gregory, *right*, seems triumphant.

In 1951, *below*, he lectures on gorilla anatomy with aid of mounted specimen.

Teddy Roosevelt, with the Museum's George Cherrie and Leo Miller, explored a Brazilian river in 1914 expedition.



Koryak warriors, in Siberia, donned armor—hide plates tied with thongs—for Jesup Expedition photograph in 1901.

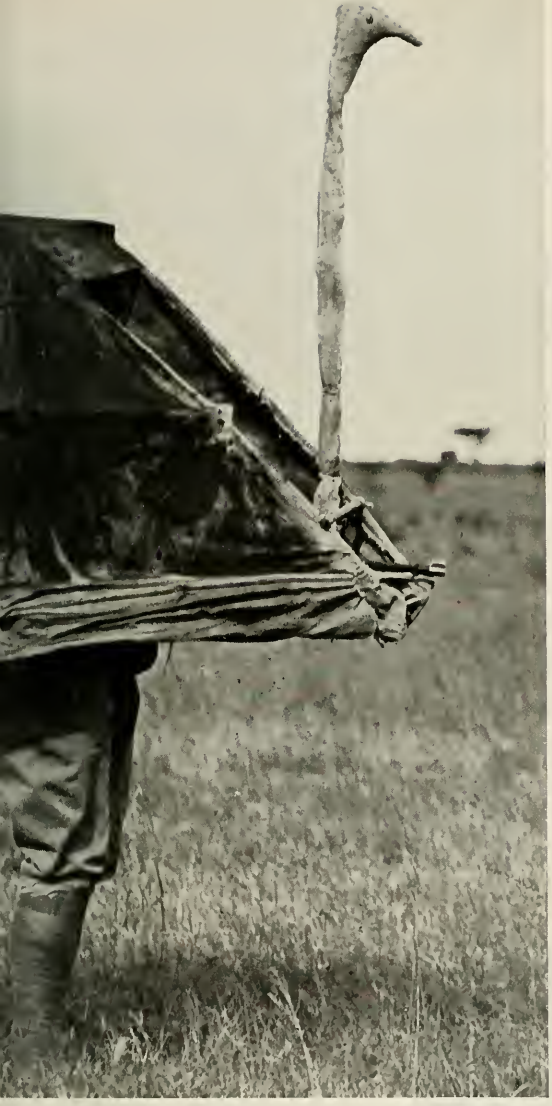
Portable blind, shaped like an ostrich, was pictured by Carl Akeley in early 1900's. Man inside could observe and

The American Museum's location made exploration in the Western Hemisphere a logical first choice, and this is the area in which most early parties worked. The interdependence of natural history's many parts, however, means that no part of the world stands alone. When chance for wider travel arose, the Museum seized it.

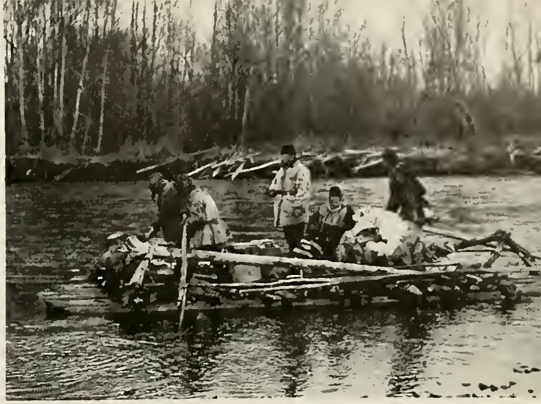
Korea—then a land of mystery, known in the West as the "Hermit Kingdom" — saw Roy Chapman Andrews travel hundreds of miles on the Yalu River in 1911.

By 1912, the Museum had thirty-five expeditions in the field and every continent except Australia had been visited.

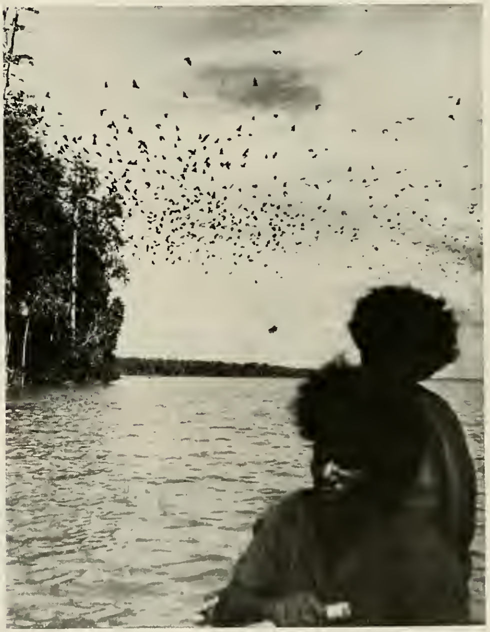
Greenland Eskimos, in 1913, reacted variously to foreign phonograph music of Museum's Crocker Land Expedition.



photograph animals, for they pay little heed to ostriches. African natives have long used such disguises for hunting.



Raft on Kolyma River, at turn of century, carried daring ethnologist Jochelson in pursuit of Siberian tribal groups.



Large fruit bats, called "flying foxes," are captured in flight by camera of 1936 Archbold New Guinea Expedition.

With the American Geographical Society, Yale, Harvard and other institutions, a party was sent to Greenland in 1913. As the years passed, seas and islands round the world yielded their secrets. The Museum was soon not just American, it was an international institution.

These world-girdling expeditions developed a *science* of exploration. Early explorers often went out only to see what could be found. But Museum parties, such as the later Archbold New Guinea Expeditions, could travel by air, and even have supplies air-dropped at predetermined points. They knew what they wanted and where to go to find it.

In the Bahamas, in 1902, the ornithologist-artist, Louis Agassiz Fuertes, made field sketches from fresh specimens.

Public Instruction

This is a dominant objective of the Museum

FROM the time of Albert Bickmore's first lectures—in fact, in Bickmore's mind long before then—public instruction has been a vital part of the Museum's work, perhaps the most important of any. The Museum's exhibits themselves are, of course, the most complete demonstrations of the way our world works that a visitor can find. Yet even the synthesis of an exhibit can be multiplied in effectiveness by the stimulating comment of intelligent teachers, who add emphasis to the content of the Museum's displays. And, any weekday, elementary school classes may be seen in the halls, benefiting from the commentary of their own teachers.

But such use of the Museum is only a part of its educational mission. Consider the "World We Live In" program, which gives some 85,000 school children each year a four-hour session in the Museum. Lessons in the exhibit halls, the opportunity to handle natural science specimens, films and demonstrations of fact and principle help to bring nature to life.

Nor does the Department of Public Instruction confine its attentions to school children. A special program exists for adults. There are field trips to nearby points that lead the city-dweller to a closer understanding of nature. Many, each year, travel the nature trail, founded by the Museum, at Bear Mountain, forty miles from the city. The teaching of teachers is another mission. Each year, a dozen Museum courses—for which academic credits are granted—are oversubscribed by student educators. Camp counsellors come to learn how best to teach natural history in the field. Nurses-in-training at sixteen New York hospitals attend lectures and demonstrations in a variety of biological subjects.

ALMOST from the earliest days, the Museum was prepared to carry its message outside its own walls. There is a substantial circulating collection of portable exhibits, which city schools may borrow for classroom and other uses. And the Museum is always glad to help educational groups set up their own exhibits and programs to suit their own needs.

LESS THAN TWO WEEKS after Sputnik I's launching, in October, 1957, the Hayden

DURING WORLD WAR II, the Planetarium helped to train navigators for military services. The time needed to acquire skill was cut by simplified procedures.

A vital element in the Museum's mission of general education is a relative newcomer to the grounds—the Hayden Planetarium. Since it opened in October, 1935, this show-place of the heavens has captured the imagination of more than ten million persons. And each year several hundred young people and adults enroll in Planetarium courses that include various phases of astronomy, navigation and meteorology.

The heart of this institution, dedicated to the natural history of the heavens, is a Zeiss projector, which was donated to the Museum in 1934 by the New York philanthropist, Charles Hayden. By next year, a new (and improved) Zeiss projector, a gift of the Hayden Foundation, will

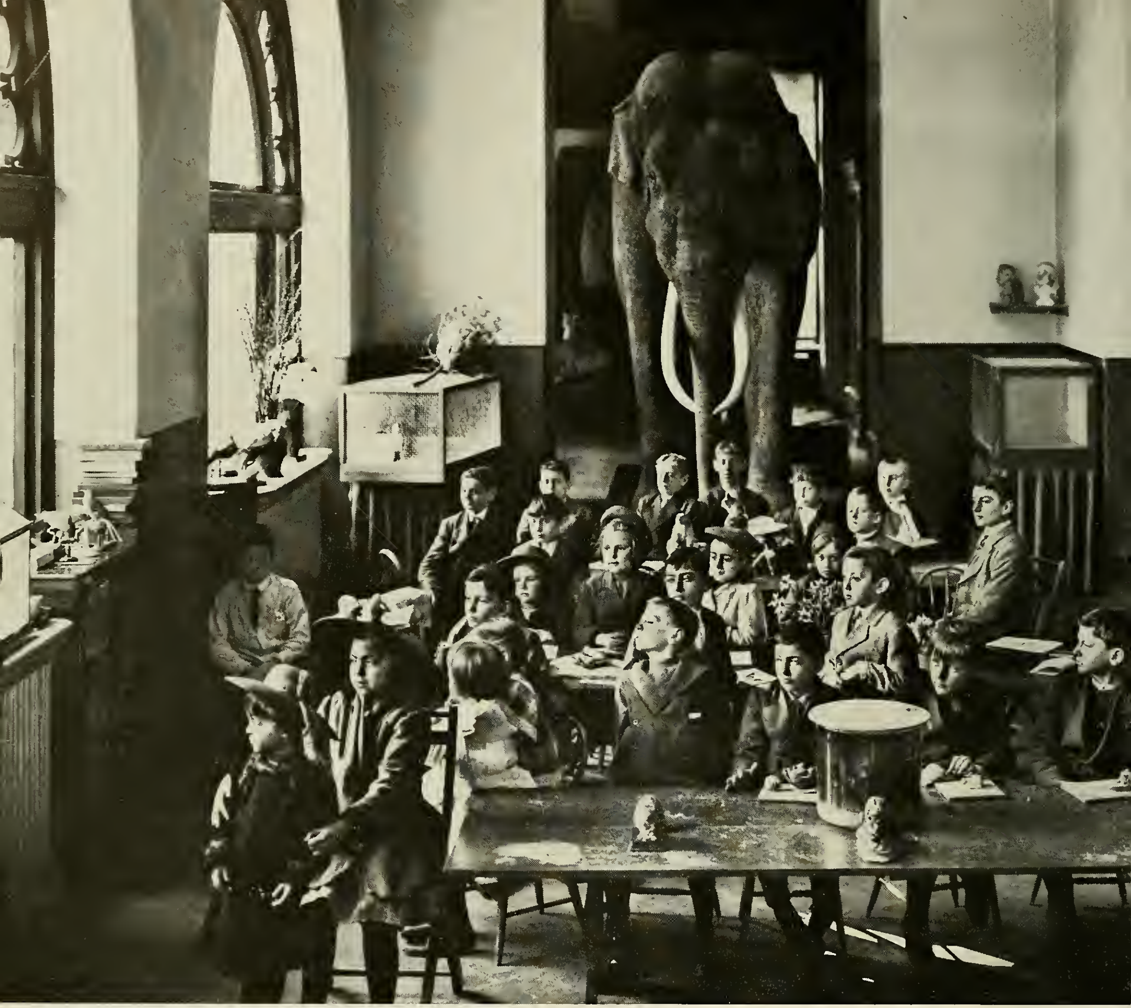
HAYDEN PLANETARIUM

Planetarium offered lectures on space, man-made satellites. The crowd, *above*, lined up following Sputnik II. 85,000 school children attended the satellite lectures last year, which may become a permanent part of astronomy program.

take the place of the original instrument. These dumbbell-shaped, optical machines, weighing two tons, have become familiar to all star enthusiasts in recent years. Turning independently on any of three axes, they project—on a hemispherical dome—the stars of either hemisphere as they appear at any time, demonstrating the changes in the night sky that occur with a change in latitude, as well as the movements of the moon and our neighboring planets.

While this great instrument is the heart of the Planetarium, it is only one of its features. The massive Willamette meteorite, (*page 196*), the Woman, a small one of three tons, and another, the Ahnighito—largest (thirty-four tons) on exhibit in the world—stand in its halls. And an enormous orrery—a Copernican model of the entire solar system, also the gift of Charles Hayden—occupies one floor.

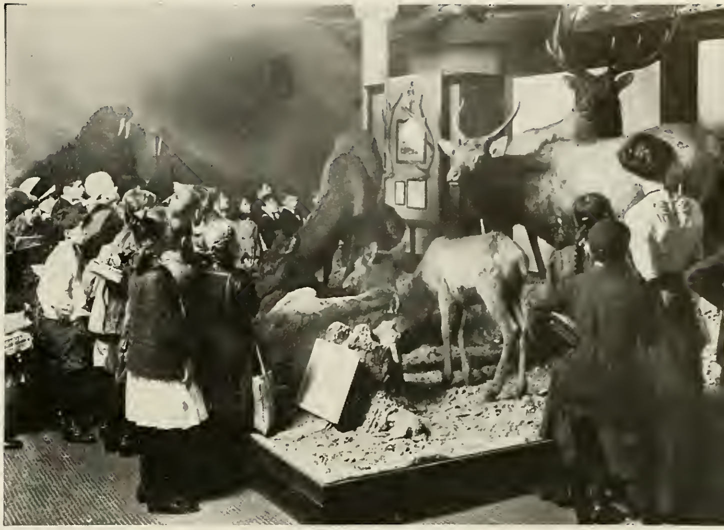
NATURE WALK through Central Park is led by Farida Wiley (pointing, *above*), Public Instruction veteran. Many of the education programs are for adults.



Indian Elephant, in 1910, dominated "Children's Room," which opened the previous year. Today's equivalent, the Natural Science Center, is host to 50,000 children a year.

Five birds in a box are typical of the pioneer circulating collections that went out to city schools in early 1900's.

Museum messenger of the same period leaves the building with boxes of specimens to be shown during school lecture.

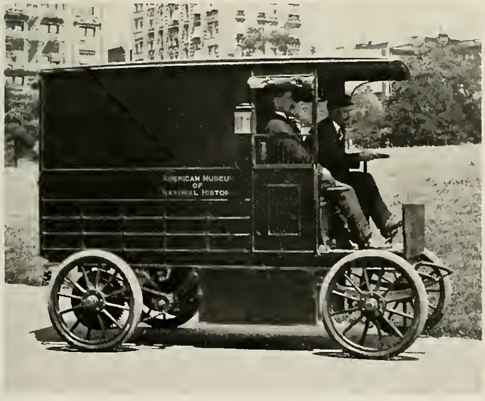


Early habitat group was a center of interest for school children in 1911, *above.* Museum instructor is lecturing. The group showed young and mature elk.

Within the busy city, the world of nature

In the urban areas of every nation, young and old alike have little chance to learn, firsthand, of woods and streams and open fields. In sprawling New York, the Museum's halls—from the earliest days—have given city children the next best thing—a look at the workings of soil and sun, plants and animals, and the changes that come with the seasons.

From the beginning, the children have loved it. The lifelike exhibits, the films and lectures, the glimpses of bright, exotic corners of the earth—all give the young visitor a realization that the whole world is not like New York. For city youngsters, these things are unforgettable, and the passionate interest thus kindled has regularly led many children to further exploration and closer study of the great world of nature around them.



An electric truck, *above,* carried collections in 1908. By 1935, *right,* exhibits traveled in this shiny panel truck.

Akeley's bust of gorilla regularly receives a thorough examination—and polish—by such young visitors as this.

This live turtle, in the Natural Science Center, with its retractable head and feet, proves a fascinating spectacle.

The young are always welcomed

To touch a bronze gorilla's nostril, to see a wolf pack loping over moonlit snow or a leopard bent over its prey, to peer at the ceiling-high bones of a dinosaur or the great bulk of a whale out of water—these are experiences children love, and what they love, they remember. When a snake wriggles through a child's hands, "snake" is no longer a word in a book—and no longer a thing to fear. When any part of nature becomes familiar through personal encounter, the whole of nature seems more inviting.

A trip through the Museum is, for a child, the next best thing to traveling round the world in the company of an omniscient guide, friendly and informative. This is why children come to this house of the world in ever-increasing numbers. This is why the Museum is geared so closely to schooling—reaching out for the thoughts of those who come to know that they are, now and forever, truly world citizens, fellow members in the community of nature.

A relief globe, *right*, helped these blind children to grasp for the first time a conception of their world as a whole.

In The Years Ahead

Some hands may be quicker than the eye, but the mind is always faster than the quickest hand. In a natural history museum, our thoughts race so far ahead of the painstaking work of creating what our minds have already seen, that the long wait between dream and reality often seems a frustrating burden. But, if we look back to see how far we have come since our start ninety years ago, that prospect should renew our confidence in where we are going.

When The American Museum's newest exhibit—the Hall of North American Forests — was opened to the public last year, it brought us a second step forward in a new exhibition program that was first announced over a decade ago, in 1947. We are about ready for the third step — the installation of the Hall of the Biology of Man. When a baby takes a single stride, it may still be a premature accident. When it lifts its foot for the third step, you know that the youngster is walking. And we know today that our "new" program is slowly, but surely, on its way. Let us retrace its course from the past toward the future.

Through more than half a century, The American Museum of Natural History has held a position of leadership in the presentation of nature — nature as it exists on its own, undisturbed by man. We speak of it as "virgin nature," in frank, though unconscious, self-appraisal of our human species as the only beast in nature with our ability and inclination to violate all we touch. Over the years, the generosity of our friends and the artistry of our staff — as the preceding pages demonstrate — have brought our presentation of virgin nature to a level of perfection perhaps never likely to be surpassed. Our "new" program, which is now more than ten years old, is in no way a replacement but rather a supplementation of the program that existed previously.

The tradition most perfectly embodied in the habitat group — with its inspiring presentation of the beauty and the fascinating interrelationships of undisturbed nature — must be supplemented for several reasons. In some respects, the habitat group — when offered by itself — places too great a demand upon our public, for the educational method of the habitat group is indirect. One of the outstanding virtues of this form of presentation is that it does not predigest the evidence. Instead, it makes a total reconstruction of a scene or event in nature, in which the effects of many natural laws and scientific principles are implicit, and from which a penetrating mind may draw many conclusions and gain many new insights.

By the same token, the habitat group also offers abundant opportunities for those not versed in scientific deduction to overlook or misunderstand these implicit messages. In fact, a habitat group sometimes seems to challenge the casual visitor to draw — from replicas of the same kind of evidence — the same conclusions that it may have taken science decades to reach from study of the originals in nature. A label in the case — or a lecture — has, therefore, always been an essential adjunct of the habitat group, relied upon in an exceptional degree to bring out all the lessons implicit in such an exhibit.

But the virtues and opportunities — and, therefore, the duty — of a museum lie in the use of the third dimension for visual demonstrations that no other type or medium of education is equipped to offer. The American Museum's new program, therefore, calls for an increased emphasis upon displays of objects or segments of nature removed from their natural surroundings and placed in an artificial arrangement derived from a consideration of some particular natural law, so as to present an explicit visual demonstration of the law's meaning and significance.

Generally speaking, the explanatory exhibit can never have the dramatic impact of that which carries its message implicitly in a "total recall" of nature. But the explanatory exhibit can have great aesthetic, as well as intellectual, appeal in a more quiet key, and it will always be infinitely more dramatic than the *labels* that try to make explicit that which is only implied in the visual contents of other displays. For it is actually the label, and not the informative exhibit, that our new program proposed to replace — to the extent possible with explanatory demonstrations in three dimensions. The aim, in its simplest terms, is exhibits explained by exhibits in interrelated series, rather than exhibits explained by labels. Both the Warburg Memorial Hall (Natural History, June, 1951) and the Hall of North American Forests (Natural History, June, 1958) provide illustrations of this blending of informative habitat groups with explanatory exhibits in the over-all presentation of their subjects.

But this increased use of the explicit method of visual demonstration is only a minor feature of the new program. Its major point of departure lies in the injection of man and his works into our presentation of nature. Man is here to stay, at least as long as museums do, and the impact of man upon his environment throughout our world has become so powerful and all-pervading that it can no longer be disregarded by any individual or institution undertaking to teach a knowledge of nature.

The traditional, and separate, exhibits of undisturbed nature on the one hand and of human life on the other — illustrated chiefly by the finer artifacts of different material cultures — have an important function to perform. But the story such exhibits tell is not complete, for it fails to bring man and nature together — omitting all mention of what lies between the two. It is the chief purpose of our new program to supply this missing chapter of an otherwise well-told tale.

Within our museum premises, the new program has its center and starting point at the Seventy-seventh Street lobby on the first floor. To the west of this lobby will be spread the record of the biological and cultural history of man — and of his adjustment to the opportunities, conditions and limitations of his environment. To the east, we shall deal with nature as the environment of man, whether marked or unmarked by his influence.

Of this series to the east, the Hall of North American Forests — as I have already mentioned — is the second unit to attain completion. The Felix M. Warburg Memorial Hall of Ecology, which was opened in 1951, was the first. Therein, we introduce the concept of nature as a whole functioning as the environment of man — influencing man's activities and modified by man's actions.

The new Hall of North American Forests continues the story of the Warburg Hall, illustrating the more important types of forests by habitat groups, with explanatory exhibits demonstrating both the principles governing the life of the forests and the relationships of forests to man. For example, both cutting by man and harvesting by nature, reforestation and natural propagation, natural enemies and friendly denizens, food cycles, and relationships to soils and to climates are touched upon.

From a presentation of the forests, it is logical to proceed to a Hall of General Botany. Any visitor to our museum will know what extensive use we must make of botanical material and knowledge in order to create a natural habitat setting for our zoological exhibits. Indeed, it might be said that our animal groups are more botanical than zoological. But, since these exhibits are primarily designed to illustrate other subjects, they do not, by themselves, create an understanding of nature as a whole.

The proposed Botany Hall may therefore be viewed as a centralized explanatory exhibit that will supplement and make more useful the numerous informative displays of botany that are already dispersed through our exhibits. Various means by which plants adapt themselves to different environments will be explained. Their methods of reproduction and dispersal, and their relationships to the animal world, will be illustrated. These relationships are strongly focused upon insects, as destructive enemies, as helpful aids of pollination, and in other associations. Before we come to the end of the Hall of General Botany, therefore, we will have had to take up the subject of entomology as it relates to the life of the plants. We propose, in the next hall, to continue the presentation — with the insects themselves as the chief objects of our attention.

By this time, we have probably looked far enough into the future to the east. Let us therefore return to the west, where the new Hall of the Biology of Man will form the first link in a future chain of exhibits trying to build a foundation for an understanding of man, both by himself and as a product of his environment. The entire concept of this series was first developed by Harry L. Shapiro, Chairman of the Department of Anthropology, more than a decade ago.

The Hall of the Biology of Man is now nearing completion. It will start with a brief exposition of man's evolution and of the physical characteristics that distinguish him from all other living beings. The form and functions of the human body will be analyzed and explained, as will be the biological problems and conditions created by the fact that man is a social, and not a solitary, organism — preferring to live in crowds instead of roaming alone.

We hope to continue with a series of additional new Halls pursuing the subject of man, as follows. First, the fundamentals of human behavior and their relationship to glands, sensory organs, nervous system, and external conditions; next, an analysis of the basic principles involved in the process of learning. By our treatment of these subjects we will have set the stage for an exposition of man as a social being in which we shall take up such subjects as the methods and paraphernalia used by various civilizations in order to develop, in the young, the mental attitudes and physical responses required of adult members of the particular type of society to which they belong. An attempt will be made to explain the different prestige patterns characteristic of different cultural traditions or different stages in cultural development according to the relative respect and powers which society confers upon such groups as its warriors, its scholars, or its traders; upon the aged and the wise, or the young and inventive, upon male or female; and upon other classifications of the individuals that compose the group.

Such a treatment of man as a social being will be followed by another new hall — dealing with the origins and spread of material culture: that is, of tools and technologies, housing, clothing, transportation, agriculture and animal husbandry, language and writing, ornamentation, ceremonial practices, and art. Through such lessons on the universality of the basic building stones of any modern material culture, however different the social structure in which they are used, we shall also help to create an appreciation of the contributions made by the entire world to the things enjoyed in any part of the world today.

These general principles — governing man's evolution and existence as a social being and a bearer of culture — will then be applied to an exposition of the origins and evolution of our own nation. Our nation grew by what it did to the nature of the continent. Forests were cleared for fields; prairies were plowed for crops; game was hunted for meat and for fur; minerals were mined for our industries. We should like to show the nature of our continent as it was before the white man arrived, and the resources it held in stock for his arrival. We would show how the American Indian had adjusted his ways of life to the environment and we would remind our visitors that the new settlers did not only suffer the antagonism of those whose territory they invaded, but also benefited from the experiences of those who were here already, in ways that were often essential to the survival of the newcomers. We would trace the cultural and biological origins of the American people, and show the contributions that divers traditions, attitudes, and skills have made toward the development of our nation. We would show how the country was changed by human activity, and how the nature of the land, in its turn, influenced the direction of human effort at various times. In short, we would try to explain to ourselves our own culture and our own country as they are today. And beyond our horizon of today we will find other goals for our efforts of tomorrow.

A. E. Parr, Director

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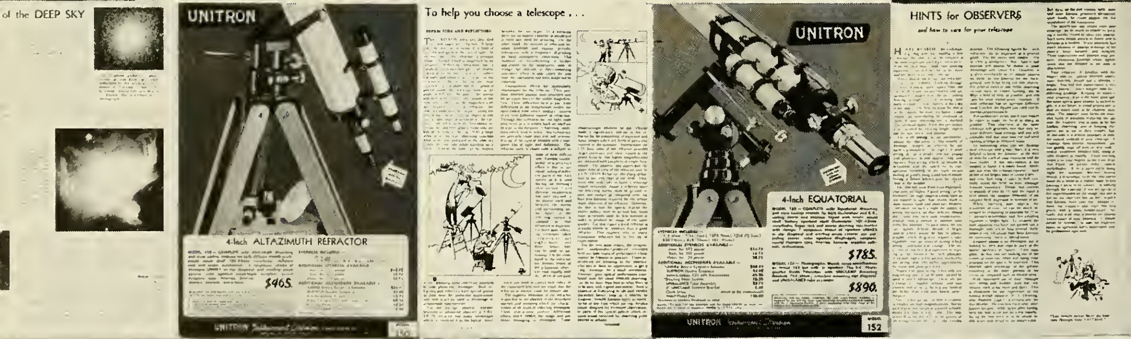

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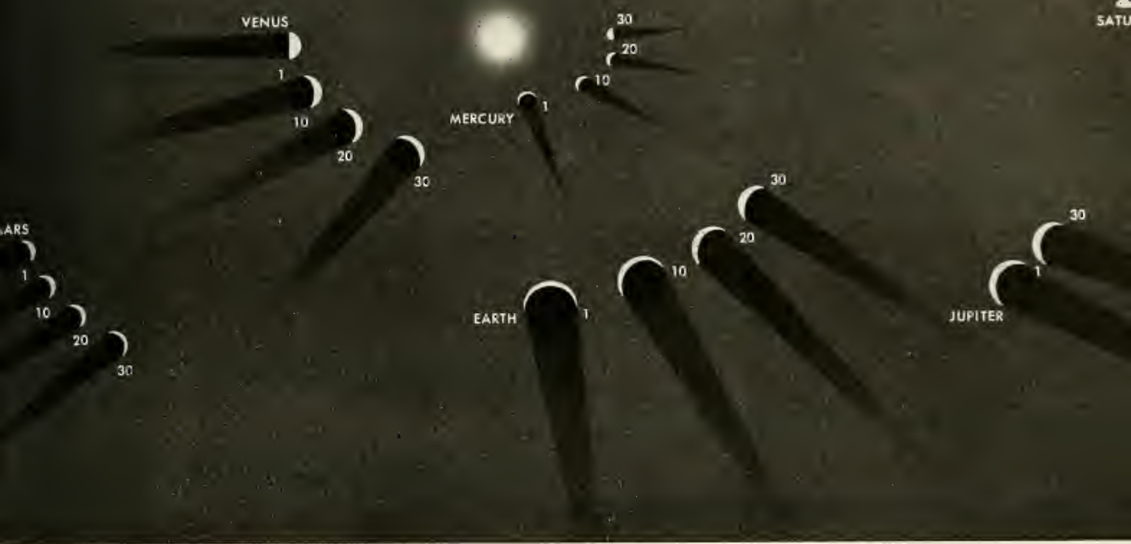
SKY REPORTER

By Henry M. Neely



THE approximate positions of the earth and the naked eye planets this month, as they might be seen by an observer high up in space, are shown, *above.* The planets' size and distances are, of course, out of scale.

All planetary motions would appear to be counterclockwise and, if the observer were to time the planets and measure their paths, he would see an interesting proof of one of Kepler's laws, which tells us that the closer a planet approaches the sun, in pursuing its elliptical orbit, the faster will be the speed at which it travels.

MERCURY, this month, is rounding the arc of its orbit farthest from the sun (reaching aphelion) and it is therefore traveling at less than its normal speed. VENUS, on the other hand, (and especially after midmonth) is in its arc closest to the sun (reaching perihelion) and the velocity of this planet is therefore greater than average.

The earth gives an interesting contrast. On April 3, it is at exactly its mean distance from the sun, so that it is then circling at average speed. But after that date, it draws constantly farther away and begins to slow down.

Early in the month, an imaginary line from the earth through MERCURY would pass close to the sun and the little planet would be hidden in the glare of the sunlight. For a few mornings, around April 26, such a line would pass much farther from the sun and, for observers on earth who have unobstructed eastern horizons, there may be a chance of seeing MERCURY in the dawn. MERCURY is not very favorably placed, however. In mid-latitudes, the planet rises only about fifty-two minutes before the sun.

Watching VENUS, and again using an imaginary line connecting with the earth, the observer in space would find that the line, this month, never falls close enough to the sun to interfere with a good view of this brilliant planet from the earth. As April progresses, the line falls constantly farther from the sun, and sky watchers with a planetary bent will see VENUS each evening a little higher above the horizon and growing gradually more brilliant.

Early in the month, the time schedule for our map is too late to catch VENUS above the horizon but, after April 15, it will be seen shining brightly among the stars of TAURUS, between west and northwest, at map times. Speeding VENUS will pass between the sun and the earth on September 1 (inferior conjunction). Meanwhile, it will outshine everything in the dark sky except the moon. It will reach almost its maximum possible brilliance in July.

It can be seen that the earth is now leaving MARS far behind in their race around the sun (Kepler's laws, again). The ruddy planet, which was so conspicuous only a short time ago, now looks quite undistinguished among the stars of TAURUS and nearby constellations (seen on the map with the bottom turned between west and northwest).

The earth, as can be seen, is getting closer to JUPITER, and the giant planet is coming into our premidnight sky as a brilliant object, growing brighter as the speeding earth nears it. JUPITER rises only a few minutes after the end of the times for using the map and, an hour later, will be unmistakable over the southeast horizon.

Add about two and a half hours to what has been said about JUPITER and it will apply to SATURN, which follows JUPITER up from the southeast. SATURN will then be found close to the familiar star formation known as the "Teapot" in the famous constellation of SAGITTARIUS, the Archer.

Mr. Neely, editor of *Sky Reporter* since 1947, now prepares this monthly feature for Natural History.

About half an hour before the indicated times for use of this month's map, *opposite*, a sky watcher at mid-U.S. latitudes can see eleven stars of first magnitude or brighter. This is the greatest number that he can ever see at one time. The sky itself will show when the ten or fifteen minutes available for observation have arrived. The time is marked by bright Rigel, in Orion, sinking to only about 5° above the horizon, between west and southwest, and the simultaneous climb of brilliant Vega to the same height over the horizon, almost due northeast.

This situation first occurs just before dawn in December, then gradually earlier through January, February and March, to the more convenient evening hours this month.

After April 10, Venus can be added to the list, and, while Mars will also be in the sky, it fades during the month from magnitude 1.3 to 1.6 so it is classed as first magnitude only during the first half of the month.

Beginning northwest, and going around the horizon through south and then east, the 11 stars are:

Capella (mag. 0.2); 39° high; NW
Aldebaran (mag. 1.1): 17° high: W
Pollux (mag. 1.2); 59° high: WSW
Betelgeuse (mag. 0.1-1.2); 26° high; WSW
Rigel (mag. 0.3); 5° high: WSW
Procyon (mag. 0.5); 43° high: SW
Sirius (mag. 1.6); 17° high; SW
Regulus (mag. 1.3); 62° high; S
Spica (mag. 1.2); 21° high; SE
Arcturus (mag. 0.2); 33° high: E
Vega (mag. 0.1); 5° high; NE

In calendar form, the events of interest this month begin April 8, when an annular eclipse of the sun will be visible over the southern Indian Ocean, Australia and the southern Pacific (but not in the United States or Europe).

April 1 to 10: It will be worthwhile to be out between 7:00 and 8:00 p.m. as the dusk deepens on April 10. Look almost due west to see Venus close by the crescent moon.

April 11 to 20: The waxing moon helps isolate Mars from the stars around it on April 13 and 14. Roll the map to bring west to the bottom to locate the two.

Saturn ends its eastward motion on April 16, and will now begin to make an apparent westward loop.

April 21 to 30: The meteors known as the Lyrids are due now, reaching maximum April 22. The moon is now almost full, but, about 3:30 a.m., it will be low in the southwest. At that hour, the observer can turn his back to the moon and, facing east, watch for a display around Vega, in Lyra, almost overhead.

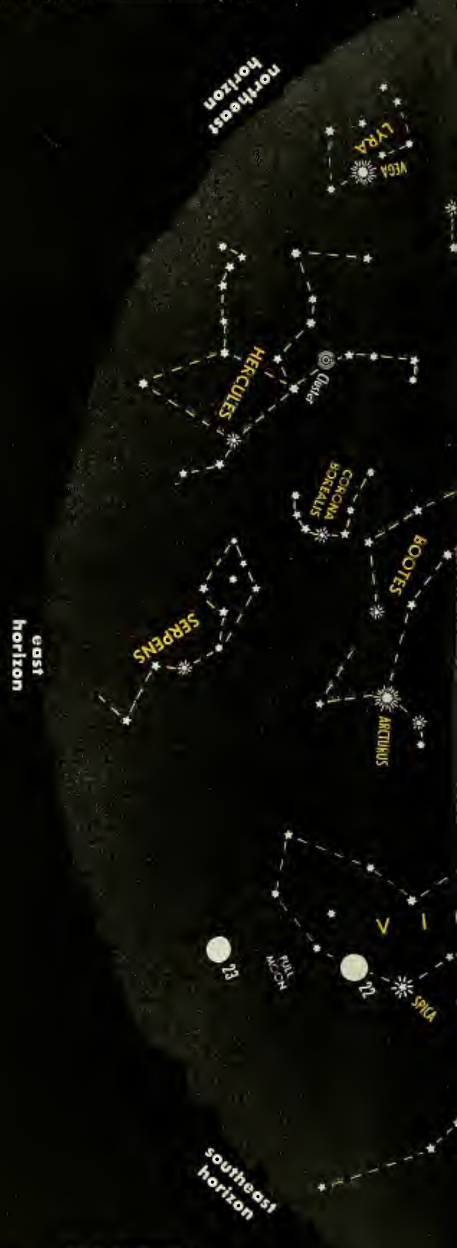
After 10:00 p.m. on April 24, brilliant Jupiter will be the only object bright enough to be seen near the full moon.

Daylight Saving Time begins on April 26 in many areas.

Beginners who feel uncertain about the part of the sky to search for stars may use the moon as a pointer on the map. Find the moon for the desired date, roll the map to bring that moon-image vertically above the horizon, face the compass direction shown on the bottom of the map and identify as many stars as possible from their relation to the moon for that night. After April 19, the moon will be so bright that only the most brilliant stars will be seen.

THE MOON'S PHASES

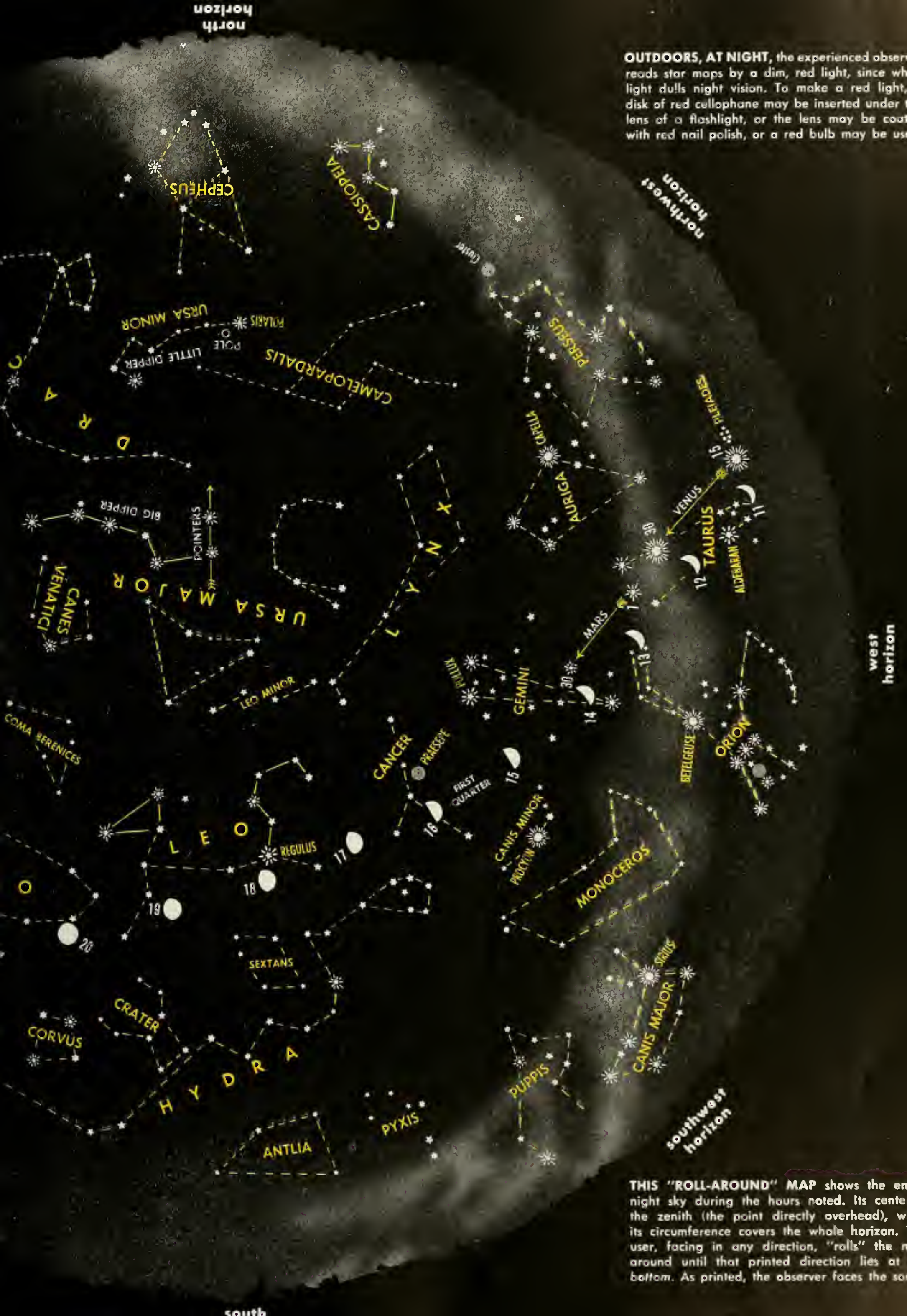
New Moon	April 7
First Quarter	April 16
Full Moon	April 22-23
Last Quarter	April 29



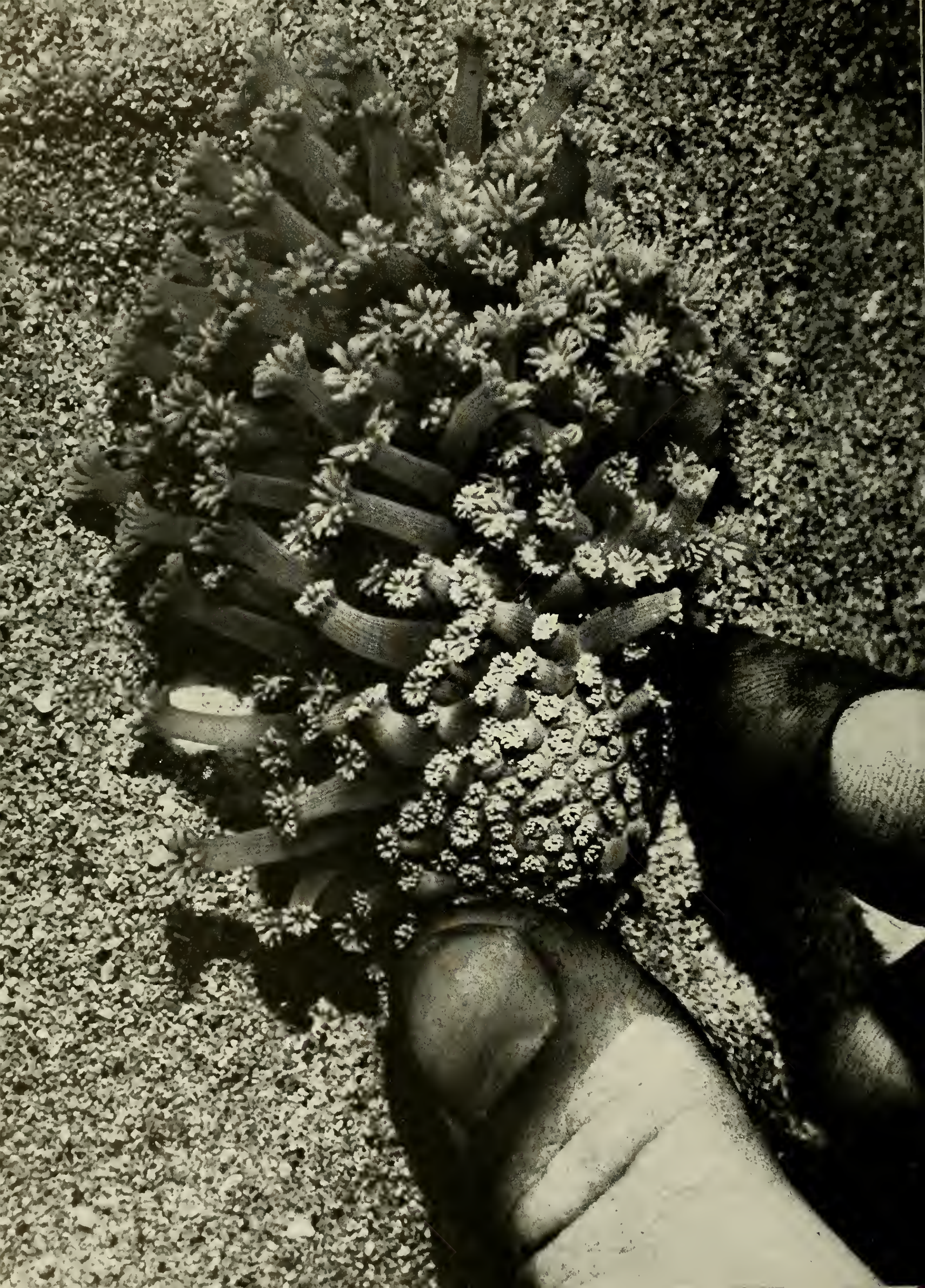
APRIL TIMETABLE

First week	9:45 to 10:45 p.m.
Second week	9:15 to 10:15 p.m.
Third week	8:35 to 9:35 p.m.
Fourth week	7:55 to 8:55 p.m.
Last week	dark to 8:35 p.m.

OUTDOORS, AT NIGHT, the experienced observer reads star maps by a dim, red light, since white light dulls night vision. To make a red light, a disk of red cellophane may be inserted under the lens of a flashlight, or the lens may be coated with red nail polish, or a red bulb may be used.


north horizon
CEPHEUS
CASSIOPEIA
northwest horizon
Cluster
URSA MINOR
POLARIS
POLE
LITTLE DIPPER
CAMELOPARDALIS
D R A C
PERSEUS
PLEIADES
CAPELLA
AURIGA
15
VENUS
11
30
TAURUS
ALDEBARAN
12
BIG DIPPER
POINTERS
URSA MAJOR
LYNX
CANES VENATICI
MARS
1
13
POLLUX
GEMINI
30
14
LEO MINOR
COMA BERENICES
CANCER
PRAESEPE
FIRST QUARTER
15
BETELGEUSE
ORION
west horizon
16
CANIS MINOR
PROCYON
LEO
REGULUS
17
18
19
20
O
MONOCEROS
SEXTANS
SIRIUS
CANIS MAJOR
CRATER
CORVUS
HYDRA
PUPPIS
PYXIS
ANTLIA
southwest horizon
south

THIS "ROLL-AROUND" MAP shows the entire night sky during the hours noted. Its center is the zenith (the point directly overhead), while its circumference covers the whole horizon. The user, facing in any direction, "rolls" the map around until that printed direction lies at the *bottom*. As printed, the observer faces the south.



THE CORAL REEFS

PART II

BIOLOGY OF THE CORALS

The community of reef organisms has had a long evolutionary history

By NORMAN D. NEWELL

AMONG ALL THE SEA'S COMMUNITIES, the organisms of the coral reef habitat are remarkable both for their diversity and for their beauty of form and color. The biological exuberance of a flourishing coral reef, with its innumerable ecologic niches and many hundreds of species, is at least suggestive of the tropical rain forest ashore. The analogy is heightened by many corals' similarity in form to terrestrial plants and the plantlike responses of the growth in some coral zones to light and shade, shelter and exposure. The community as a whole, including representatives of every phylum of the animal kingdom and several primitive forms of the plant kingdom, forms a balanced, mutually dependent association of organisms. Such a reef community may exceed 3,000 species in number, each with its own particular ecological requirements.

Recent work on the organic productivity of coral reefs, conducted at Bikini and Eniwetok, indicates that the attached reef algae form the base of the food chain, drawing their energy from sunlight and their nourishment from dissolved phosphates and nitrates brought to the reef by ocean currents. It appears that these low forms of plants synthesize virtually all of the food needed by the herbivorous reef animals. But the key animal in this environment—the reef coral—does not feed on plants. Corals are carnivores that possess a central mouth surrounded by circles of tentacles, armed with stinging cells and cilia, used in the capture of small animals of the plankton.

A majority of reef corals feed at night, when the herbivorous planktonic animals are most actively grazing on the reef algae. While feeding, the coral polyps expand, with tentacles extended in a manner resembling small flower blossoms. Because of their attached condition, food supplies must be brought to the polyps by water circulation, which also flushes harmful sediments from the surfaces of the living animals. Some reef corals form branching, shrublike, or treelike colonies: others form rounded or incrusting masses of hundreds of thousands of individual polyps, organically joined together. Such a colony is virtually a single animal, with its many mouths directed upward and outward into the surrounding water.

The corals are coelenterates—as we have seen, closely related to the sea anemones from which they differ in possessing a calcareous base, or corallum, secreted by specialized cells of the basal epidermis. The main function of this calcareous support is to provide the living animals with a suitable attachment to the substrate.

The corals reproduce themselves both sexually—by eggs and sperm—and by budding. The eggs and sperm, which are produced by each polyp, rarely ripen simultaneously in a single individual. Fertilization usually occurs by sperm drift into the body of a "mother" polyp—an individual possessing ripe eggs. From this polyp's mouth, transparent, ciliated larvae emerge in due course—to float for days or weeks with the oceanic currents. In this way, each species of coral becomes widely distributed wherever conditions permit colonization. These larvae—each less than a tenth of an inch in size—settle to the bottom and begin to secrete the characteristic calcareous pedestal.

All reef corals are colonial organisms: that is, after the metamorphosis of the free-floating larva, the coral grows by a process of budding whereby daughter individuals remain organically attached to the mother. This multiplication of individuals continues until the cluster attains an optimum size for the species under existing conditions. Some very large colonies measure eight or ten feet in diameter and contain thousands of individual animals, each assimilating food and oxygen from the surrounding waters and reproducing itself in larvae or buds.

Not all corals, however, are reef corals. Some species occur at great depths and in quite cold waters. From these, the true reef corals differ mainly in the possession of symbiotic algae, the zooxanthellae that are directly embedded within them—for the most part in the coral's endoderm. Many reef animals beside the corals also possess symbiotic zooxanthellae. These algae obtain their food and carbon dioxide from the animal metabolism of the host: the coral, in turn, receives oxygen, and possibly carbohydrates, from the plants.

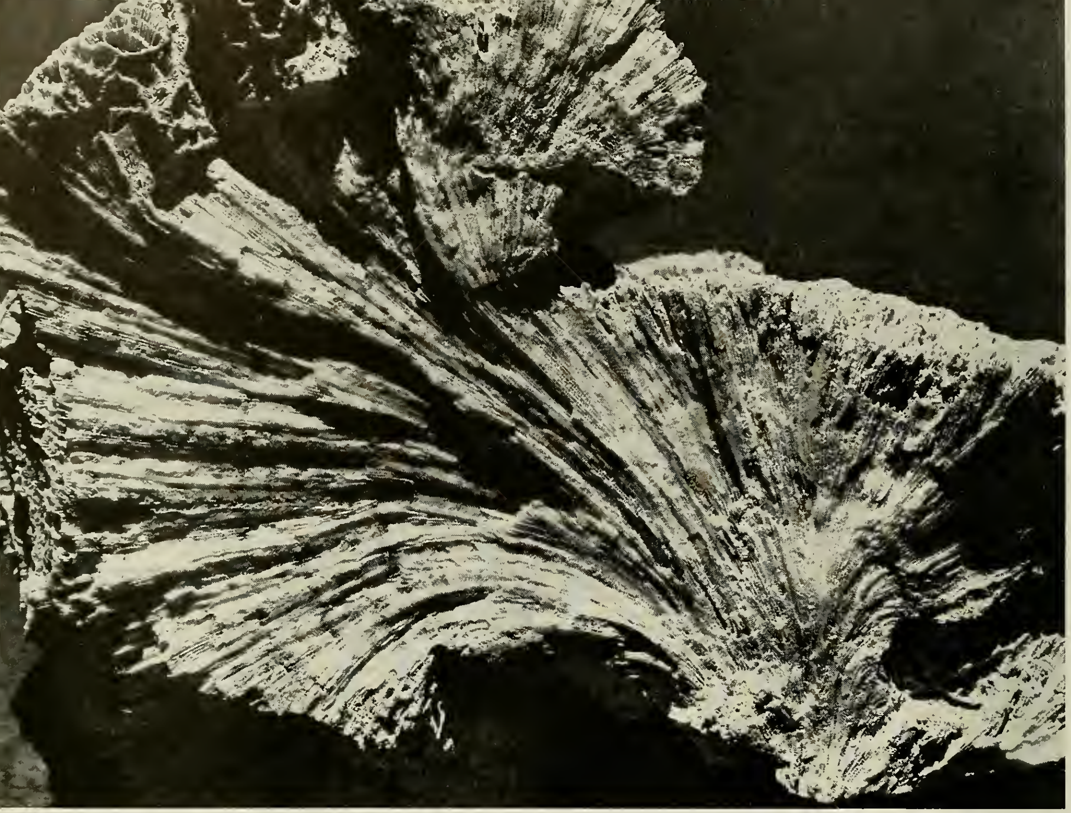
The simple structure and globular form of the zooxanthellae make them difficult to classify, but it has been suggested by several investigators that they may be dinoflagellates in disguise. Recently, scientists at the Haskins Laboratories extracted zooxanthellae from jellyfish, anemones and corals and placed them in suitable media. After a few days, the simple cells developed flagella and began to swim. In this form, they had already been described as the dinoflagellate, *Gymnodinium adriaticum*.

These one-celled symbionts grow best in warm tropical waters (25° to 29° C.) of normal salinity (3.6 to 3.9 per cent), and they require sunlight to effect photosynthesis. Consequently, the host corals, which survive symbiotically with the microscopic algae, are restricted to shallow waters with an optimum depth of twelve to fifteen feet.

The limestone skeleton, over and within which each coral polyp lies, is a white, hard form of aragonite, a relatively soluble kind of calcium carbonate. In addition to the polyp's basic limestone plate of attachment, there may be a cup, or a calyx, containing radial blades (or septa) numbering six or some multiple of six. The spaces between the septa are large enough to contain much of the polyp when it is contracted. The structure and form of the skeleton is highly characteristic for each species of coral.

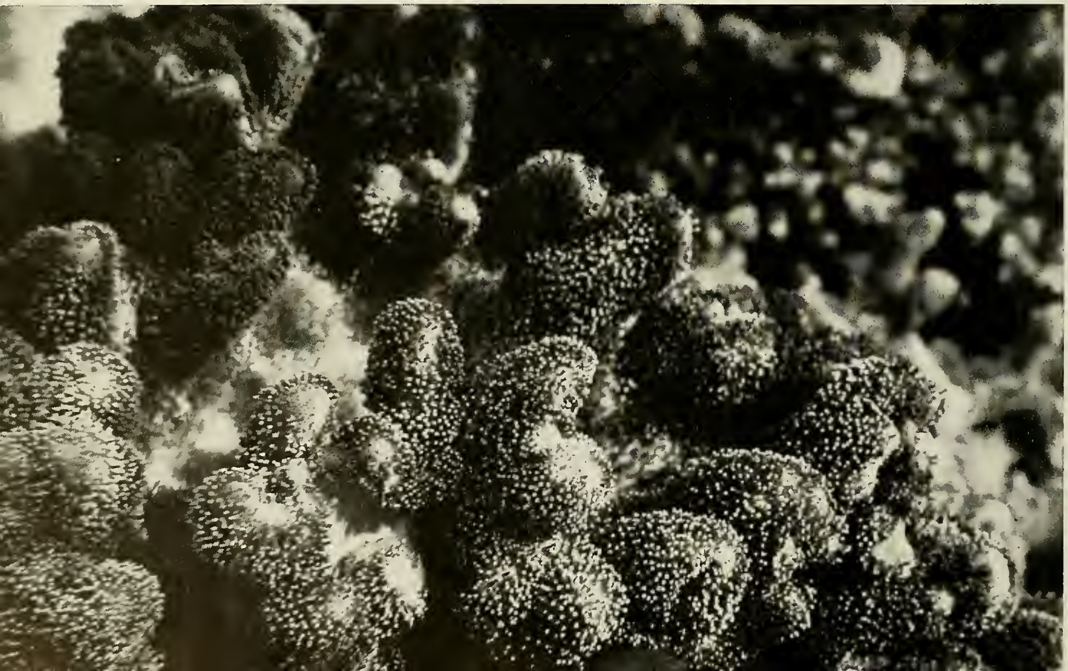
Experimental work has shown that the calcium carbonate that makes up the skeletons of marine organisms is

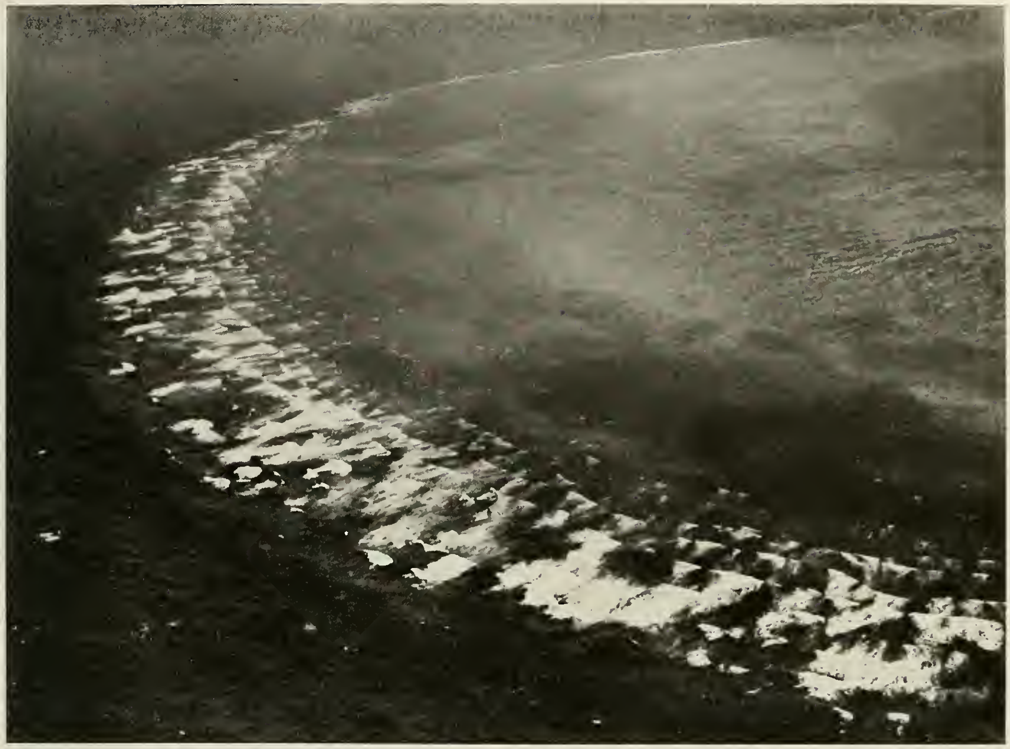
FLOWER-LIKE POLYPS of coral colony are really individual animals that act as one unit. *Left*, they retract from touch.



STONY SKELETON on which polyps live, *above*, is made up of calcium carbonate, with each polyp lying in a shallow cup. As the colony grows, skeleton expands upward and outward.

KNOBBY GROWTH FORMS characteristic of many reef corals (those *below* are from Great Barrier Reef) enable colony to expand without excessive crowding of the individual polyps.





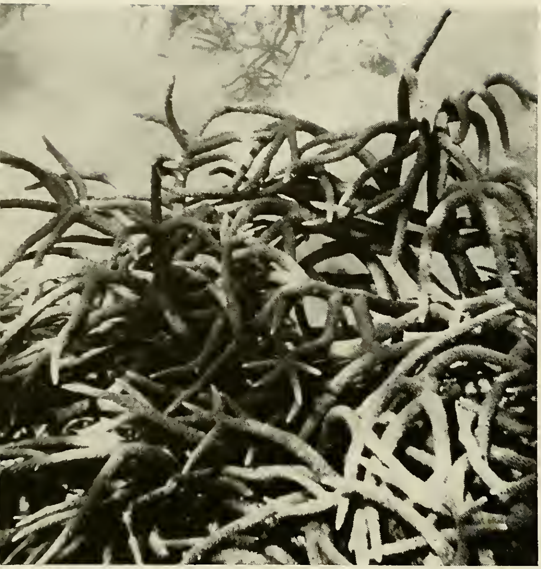
Arcuate reef front, seen in the aerial view *above*, grows seaward against breaking waves. Coral reef's organisms are stimulated by the well-aerated, sediment-free turbulent zone.

Marginal rim of limestone, *below*, laid over reef skeleton, helps protect polyp colony. Wave-resistant rim is made by species of algae inured to harsh conditions of reef surface.

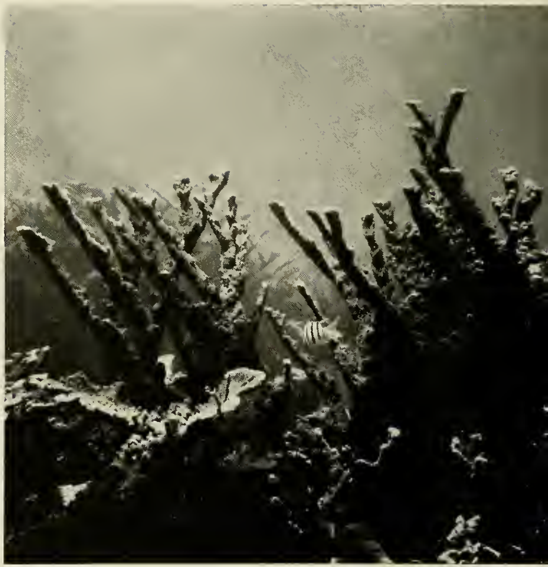
extracted directly from the surrounding sea water. It is taken into the body fluids in the ionic state, and then deposited from a mucous-like substance by means of special lime-secreting cells. The carbon dioxide metabolism is controlled by an enzyme known as carbonic anhydrase.

Now, calcium carbonate is much less soluble in warm than in cool sea water. Precipitation in warm water, therefore, requires less energy than in cold water. It is probably because of this favorable energy factor that great modern marine deposits of limestone—including the coral reefs of this study—are found only beneath warm seas.

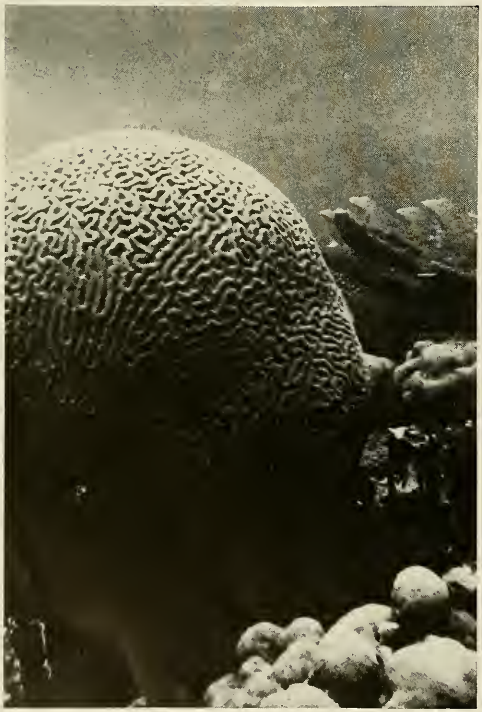
Skeletons of dead corals are the chief building blocks of modern reefs but these alone are not capable of producing firm reef limestone that will withstand the strong waves of the open ocean. A number of species of reef algae of the Lithothamnion group — of the family Corallinaceae (especially the genus *Porolithon*)—have become adapted to the conditions of frequent exposure to sunshine, air and strong surf of the seaward edge of coral reefs. These plants, which also are capable of calcium carbonate metabolism, lay down incrusting, thin deposits of enamel-like limestone that is spread over the skeletons of dead corals, welding them into firm but porous rock. These coralline algae reproduce by means of tiny spores,



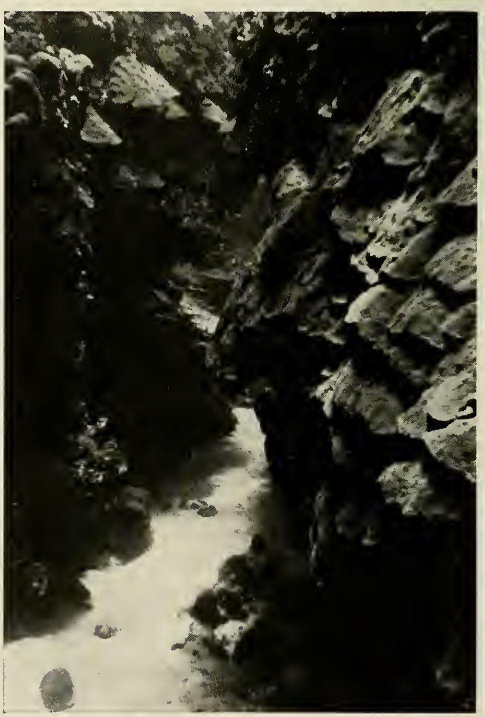
STAGHORN CORALS, *above*, belong to common genus *Acropora*. Fast-growing, branching *Acropora* is found the world over; staghorn inhabits waters of moderate depths and turbulence.



ELKHORN SPECIES, also of the genus *Acropora*, forms treelike colonies often many feet in height. It is characteristic of the shallow, very turbulent waters of coral reef's outer margin.



"BRAIN CORALS," so called because of meandering furrows, have solid, mushroom-like form common to organisms of many reef coral species, found in quiet and turbulent seas.



DIFFERENT SHAPES are found in corals of same species as result of variations in slope, turbulence and light. *Above*, *Montastrea annularis* is shingle-like; at *right*, it is lobed.

Curator of Historical Geology and Fossil Invertebrates at THE AMERICAN MUSEUM. DR. NEWELL is also Professor of Geology at Columbia University. The first half of his review of the coral reef questions appeared last month.

which may float for long periods with the ocean currents before settling on favorable shoal areas exposed to the beneficial action of the waves. Representatives of the Corallinaceae are widely distributed in all tropical seas but—for reasons not yet understood—they do not now form protective, marginal deposits on West Indian reefs. It is this deficiency in protective deposition that is responsible for many of the characteristics of these reefs.

IN PART I of our coral study (NATURAL HISTORY, March, 1959) we reviewed the competing theories that account for the growth of coral reefs. We concluded that new information, derived from studies during and following World War II, had demonstrated elements of correctness in both the major competing theories—Darwin's (and others') "submergence" view and Daly's (and others') alternative of "variable sea level." Further, we noted the marked contrasts between the massive, oceanic coral growths of the Pacific and those comparative newcomers among coral reefs that are characteristic of the West Indian province. In particular, we cited the work of W. M. Davis as first making clear the strong differences between West Indian and Pacific formations. In completing this study, it is fitting that we should note the effects of recent research on Davis' hypothesis.

One of the most stimulating of Davis' deductions about the West Indies was his view that many of the great submarine terraces and banks of the region represented preglacial barrier reefs around broad, flat lagoon deposits that had been modified somewhat by low level wave abrasion after the corals were killed by glacial cooling. Evidence bearing on his conclusion is still limited mainly to submarine topography of the limestone platforms, and there are all too few precise surveys of the bottom topography in the West Indian province. Nevertheless, converging lines of evidence tend to support Davis' thesis that the banks overlie great Cretaceous and Tertiary reef and lagoon deposits that are totally unrelated to the small living reefs found in the region today.

Daly, in contrast, believed that these submerged platforms might be entirely the product of Pleistocene low-level erosion and, therefore, that they should be quite unrelated topographically to the character of pre-Pleistocene rocks. That Daly's belief cannot be true is demonstrated in the Bahama Islands, where the present surfaces of all but the margins of the banks are depositional, and *not* erosional, plains. Furthermore, as Davis has convincingly shown, the volcanic islands of the Lesser Antilles are *not* simply erosional remnants, rising above surrounding wave-cut platforms of the same material. Instead, they are the nuclei around which limestone platforms were deposited, and their present form has been only partly modified by the low-level erosion of the Pleistocene period.

The exceptionally widespread distribution of certain Cretaceous and early Tertiary limestones throughout the West Indian region indicates generally clear waters, favorable for reef corals, at those times. The fossil record of the West Indian corals shows that they were more varied in early Tertiary times than now and that the climate was appreciably warmer and more favorable for reef growth. Vaughan (1919) found that fossil reefs of Oligocene age are very widely distributed in the Caribbean area. Since his studies, reefs of this age have been recognized in deep borings far below sea level around the Gulf of Mexico, where the adjacent sea is now too cool and too muddy to support living reefs.

Recent deep borings in Florida and the Bahamas, supplemented by geophysical soundings over the adjacent sea floor, show that more than two and a half miles of calcareous rocks—similar to lagoon and reef deposits of the South Pacific—underlie the continental shelf. This evidence dramatically confirms Davis' belief that the submerged platforms of the West Indies were in many cases formed of calcareous sediments laid down on a subsiding floor. Did this West Indian combination of calcium carbonate deposition and slow subsidence produce great oceanic reefs in the Darwinian manner?

THE edge of the continental shelf of North America, between about 32° and 20° north latitude, is one of the most remarkable physiographic features on earth. The true edge of the continent, along the outer margin of the Bahama Islands, rises precipitously — two and a half miles out of the depths of the ocean—in an escarpment as abrupt and impressive as any in the world. In the area of the Bahamas, the continental shelf is flat and generally less than ten fathoms deep, interrupted here and there by deep, canyon-like trenches that divide the shelf into separate platforms, similar to sediment-filled oceanic atolls. These platforms are bounded by marginal cliffs and slopes too

CORAL REEF ASSOCIATIONS may vary greatly, since differences in shade and shelter produce the so-called reef niches, or

steep to have been formed from unconsolidated materials.

The Bahama area is the more remarkable because the record of a deep petroleum test, and many deep-sea cores and geophysical soundings taken by scientists of the Lamont Geological Observatory of Columbia University, indicate that most of the continental shelf here—as underneath Florida—is composed of nearly flat-lying limestone, dolomite and anhydrite beds that have accumulated since the Jurassic period, a hundred and thirty million years ago. These rocks must have been deposited in shallow waters behind an outer reef barrier. The marginal escarpments around the banks and at the edge of the continental shelf do not have the form of faults, and geophysical evidence from seismic and gravity surveys indicates that these features are *not* earth fractures.

The shelf edge resembles the Great Barrier Reef of Australia in dimensions and form, and the isolated banks of the Bahamas are similar to certain Pacific atolls in most respects, excepting that the living Bahamian reefs—like all West Indian reefs—are restricted to very shallow waters well inside platform margins. The most probable explanation of the steepness of the marginal escarpment which, along the Blake Plateau north of the Bahamas, averages as much as 60° for thousands of feet and is vertical for short intervals is that it is formed of dead coral reefs.

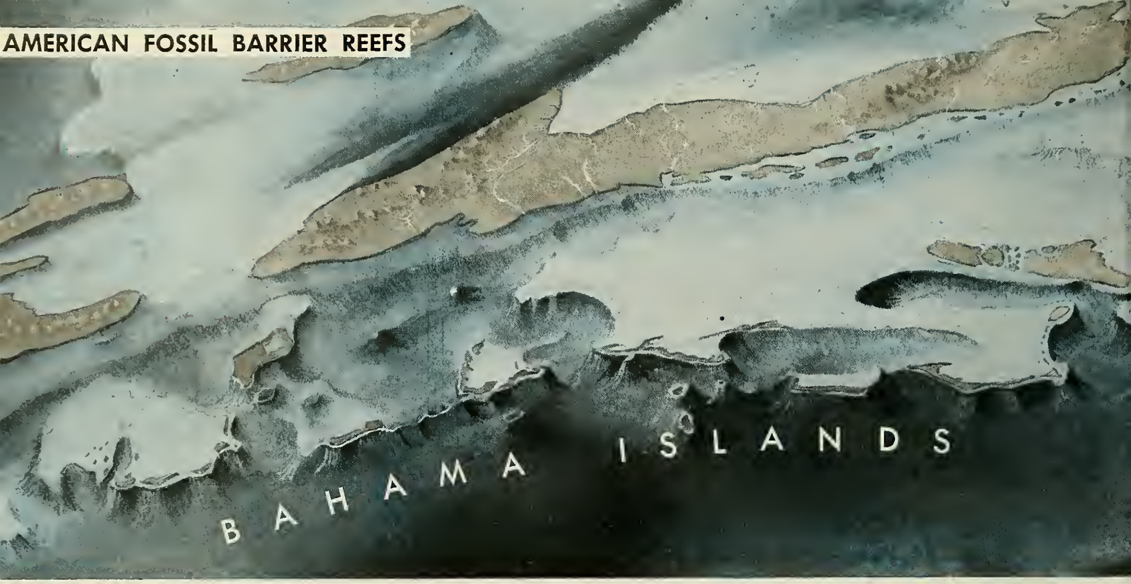
In this view, the reefs were first established around a volcanic arc like the Lesser Antilles and for a long time maintained a position near sea level by upward growth during subsidence, in exactly the manner suggested by Darwin for Indo-Pacific reefs. Evidently, reef growth and accumulation of calcareous sediments terminated first in the north, on the Blake Plateau opposite the Florida-Georgia boundary. This limestone plain, now submerged under half a mile of water, has yielded Miocene fossils to the Lamont scientists. Death of the barrier reef must have occurred in the Miocene—probably caused by increasing coolness and turbidity of the surface waters.

Upbuilding of the Bahamian and Floridian reefs continued, however, until they were killed by the onset of glacial climate during the Pleistocene epoch. The reef communities of this area have only recently been reestablished—with the gradual warming of post-Pleistocene climate—on the shallowest parts of the eroded surfaces of Tertiary reefs and other rocks.

Other great, steep-walled limestone shelves—similar to the Bahama banks and the Blake Plateau—occur along the west side of Florida, north of Yucatan (the Campeche Bank) and east of Honduras (the Mosquito Bank). The island of Cuba is also bordered by limestone banks, while others lie between Jamaica and Central America.

To summarize this review, we now know that such controversies as subsidence versus shifting sea levels are not necessarily resolved by mutually exclusive answers. It seems probable—in the light of evidence that was unavailable when the controversy originated—that living reefs, generally, are comparatively thin growths over the weathered and eroded surfaces of older rocks. Some of these older rocks, in turn, are fossil reefs that were dead before the present reefs started their growth. The study of the West Indian coral reefs is most illuminating in this regard, and the knowledge gained from such studies aids in understanding the origin and history of coral reefs everywhere in the world.

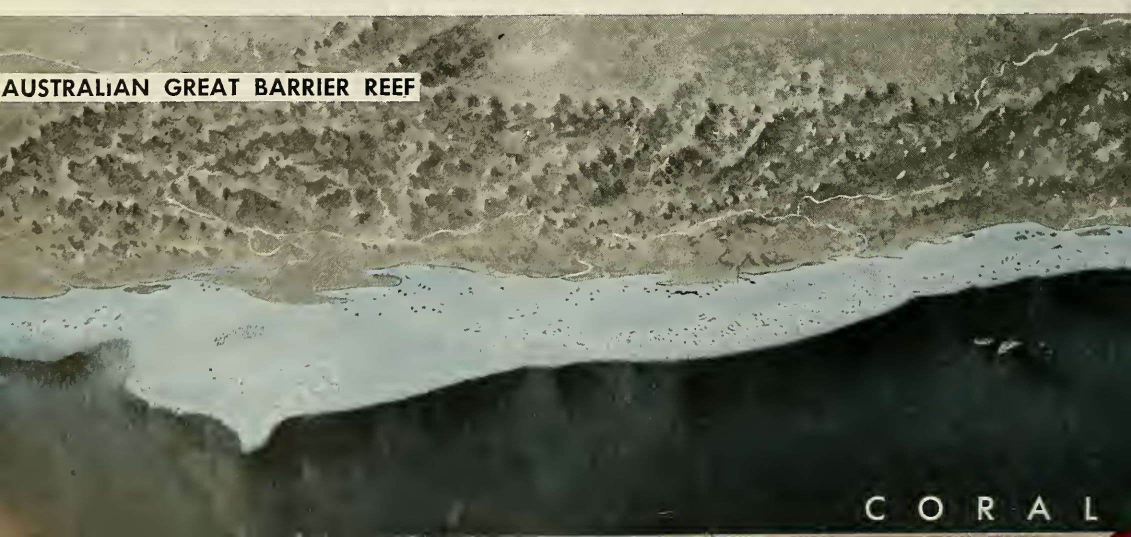
microhabitats, occupied by organisms specially adapted to them. *Below*, mushroom and elkhorn corals of a Bahamian reef are found in association with slender, flexible stalks of gorgonians, distant coelenterate relatives of the stony corals.

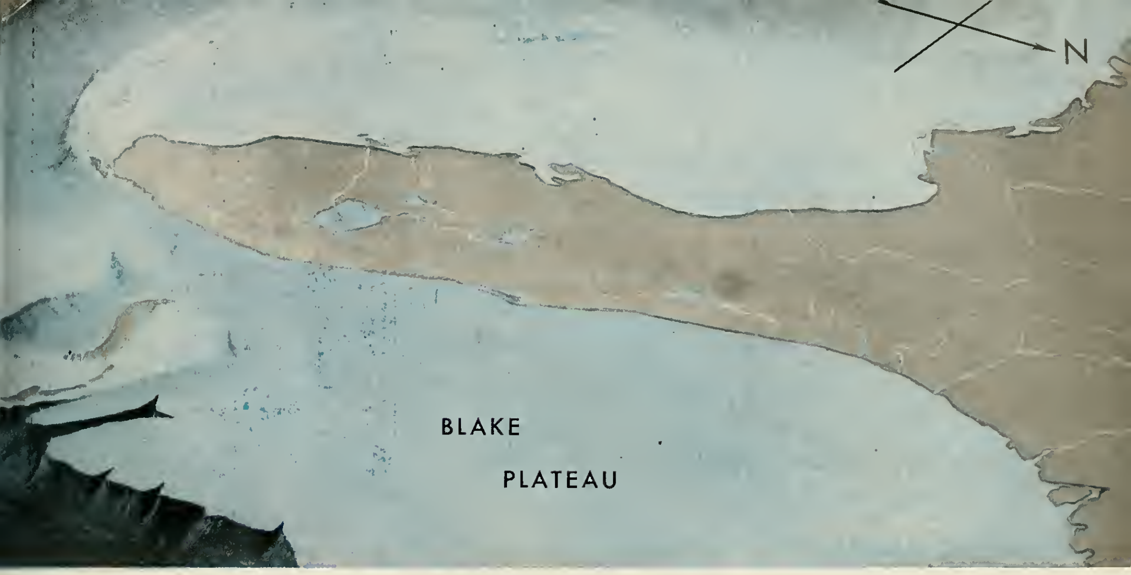

AMERICAN FOSSIL BARRIER REEFS

THE WARM, CLEAR, SHELF SEAS of southeastern North America, *above*, and eastern Australia, *below*, support many living coral reefs—of which the best examples lie along the shelf rims, where they are exposed to the beneficial effect of brisk trade winds. The most luxuriant reefs in the world, including the Great Barrier Reef, lie along the Australian shelf edge for some twelve hundred miles, forming a sea-level rim that obstructs navigation. Several hundred species of reef-forming corals are found in these reefs. In contrast, the continental shelf of southeastern North America—although climatically and geologically similar to that of eastern Australia—supports only small, scattered reefs and only thirty-five species of coral.

The shelves of the two regions are similar in many ways and they are geologically unusual. Why, then, are their coral reefs different? The differences clearly are not a result of unlike climates, because they occur within the same belts of latitude, north and south of the equator. Temperatures and other environmental characteristics are similar in the two areas. The differences stem from unlike histories of the Australian and American reefs.

Since about the middle of the Miocene epoch, the western Atlantic reef province has been isolated from other coral reef areas. West Indian coral reefs have gradually become more restricted geographically and the varieties of coral have dwindled. During the Pleistocene epoch, tropical America was affected by cooling from the continental glaciers, and many of the Atlantic coral reefs of preglacial times were killed. The living reefs of the West Indies, today, are thus very young, dating from the last few millennia of the postglacial interval, and they occupy sites near shore in very shallow waters. The eastern Australian reefs, and many others of the Indo-Pacific region, were more remote from glacial centers. There-

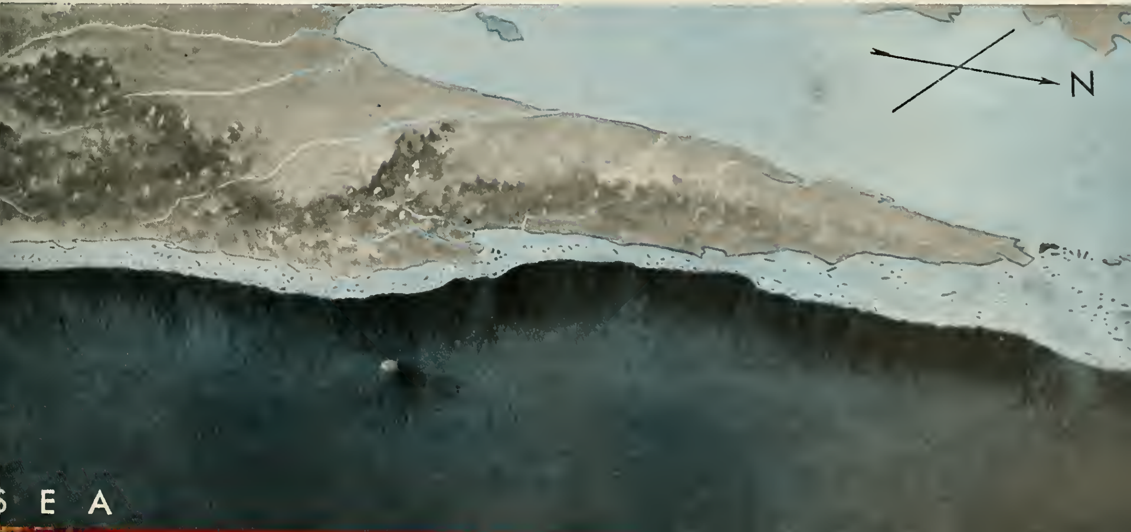

AUSTRALIAN GREAT BARRIER REEF

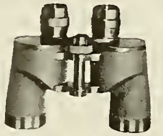


fore, they were not so much affected by adverse temperatures and growth probably was not greatly retarded.

THE great physiographer, W. M. Davis, had suggested that many of the submerged limestone platforms of the West Indian region might be ancient coral reefs of pre-Pleistocene age, eroded to low levels during the glacial stages. Deep borings in the Bahamas now reveal an astounding thickness—two and one-half to three miles—of shallow-water limestone and anhydrite, accumulated in sheltered lagoons behind shelf-edge barrier reefs that must have been vastly greater than any now living in the region, comparable to Australia's Great Barrier Reef.

The most probable explanation of the remarkable marginal escarpment along the Blake Plateau and the Bahamas, *above*, is that it is the front of a drowned barrier reef comparable to the Great Barrier Reef. Like that reef, it must have been built upward—during millions of years of slow subsidence—by the growth activities of reef-building organisms. In tropical America, reef growth and accumulation of calcareous sediments evidently terminated first in the north over the Blake Plateau, an area that is now drowned under more than half a mile of the Atlantic. The death of the reefs here may have resulted from increasing coolness and muddiness of the water during the Miocene epoch. Upbuilding of the Floridian and Bahamian reefs continued, however, until they were killed by glacial cooling some 600,000 years ago. In the warmer areas to the south, the reef communities survived during successive glacial stages. There was limited reef growth during interglacial stages but the present reefs did not become established until warming of the post-Pleistocene climate again provided the water temperatures required by the coral animals.





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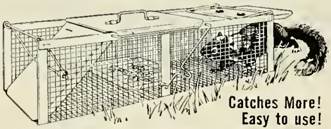

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REVIEWS

(Continued from page 177)

John R. Saunders, chairman of the Museum's Department of Public Instruction, offers a sampler of twenty-five natural history hobbies — ranging from collecting butterflies and feathers to making casts of animal tracks and raising tropical fish. A short bibliography tells young readers where they can get more detailed information about particular hobbies. The publishers, however, have not been successful in solving the inexpensive illustration problem.

The detective story fascination of paleontology adds to the interest of *Millions of Years Ago* by Edwin H. Colbert, Chairman of the Museum's Department of Geology and Paleontology (CROWELL, $2.75; 153 pp.). His little book not only gives a summary account of life in North America from mid-Paleozoic times but describes clearly and interestingly how a paleontologist works in the field and in the laboratory to find, collect and reconstruct fossil life. Skillful black-and-white illustrations by the author's wife, Margaret M. Colbert, add real charm.

ONE of the Museum's newest major exhibits is the Hall of North American Forests, which opened last spring. The event, and its by-products, are a fitting conclusion to this survey. Jack McCormick, in charge of vegetation studies at the Museum, took a major part in creating the exhibit. He has now developed its major theme in *The Living Forest* (HARPER, $3.95; 127 pp.). He shows the forest as a community with complex ecological interrelationships, food chains and a built-in system of checks and balances. Anyone who would like to know the basic facts about this forest community — which, in turn, are the underlying facts of forest conservation—can make good use of this study.

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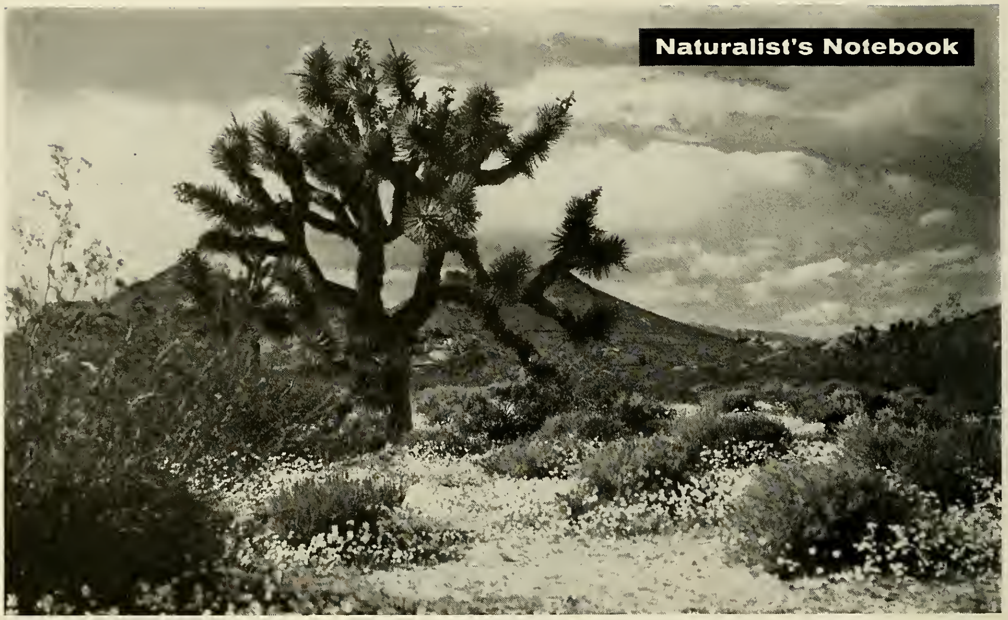


Tickseed blossoms surround solitary Joshua tree (an arborescent yucca), forming a brilliant yellow carpet over the desert.

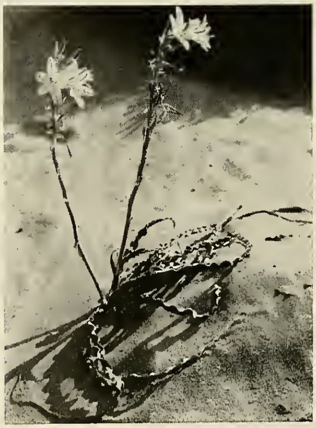
FLOWERING DESERT

By Jack McCormick

The deserts of California, far from being barren wastes, boast more than seven hundred species of flowering plants. A number of these are shrubs that dot the landscape year round, but many are herbaceous plants that rise from the sandy and rocky soils and bloom for a brief period during the late winter and spring. Almost every year, the blossoms of such perennial plants as the desert lily, and of a few annuals like the desert sand verbena and dune primrose, soften the austere beauty of southern California's Colorado Desert. But periodically, after particularly wet winters, billions of annuals blanket the desert with a rainbow-hued "floor show" more lavish than any yet planned by man, as the photographs seen on these pages — taken by a Los Angeles landscape architect, Ralph D. Cornell — show.

Through the long dry season, many desert perennials persist as roots, bulbs or underground stems, with few or no leaves exposed to the sun and wind. The ephemeral annual plants, on the other hand, produce their seeds in the moist season, before withering and dying at the onset of summer. The seeds lie dormant until watered by seasonal cloudbursts, then germinate and pass their brief time as flowers in the sun.

Through the dry summer, the Coachella Valley, in the desert near Palm Springs, is a barren, sandy waste studded with scraggly creosote bushes and salt bushes. But the moist spring transforms the area into a supreme garden of wildflowers draped with the hairy, sticky stems and purplish-red flowers of the desert sand verbena and coarse, green stems and large white flowers of the dune primrose, photo at *right*. The cool, snow-covered peaks of San Gorgonio, in the San Bernardino mountains, form in the distance a contrasting backdrop for this desert spectacular.



Desert lily from the Borrego Valley, at *left*, is one of the desert's perennials that flower in spring after spending winter as a bulb sheltered beneath the ground.

Plant ecologist on the staff of The American Museum, Dr. McCormick is in charge of vegetation studies.

Cactus flowers at Big Bend National Park, Texas

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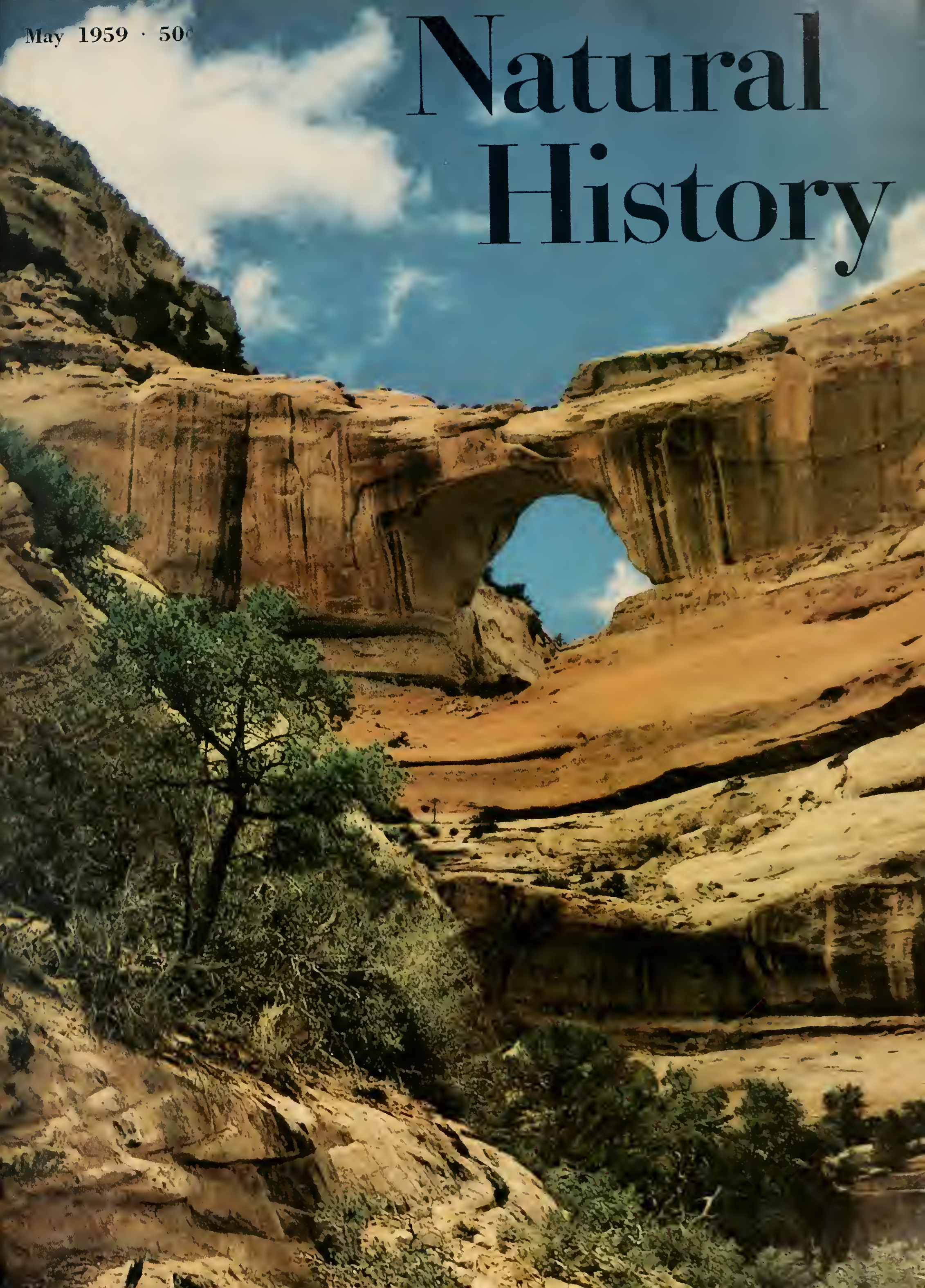

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THE marvelously sculptured landscapes of southern Utah—and, particularly, the area which has been preserved as Arches National Monument—are a spectacle that fascinates tourist and geologist alike. Seen on the cover, this month, is one of the natural arches that are to be found in profusion in the vicinity of the Salt Valley anticline. It is called Musselman Bridge and has a span of 175 feet.

In most areas where the endless works of erosion are prominently displayed, it is commonly believed that a substantial part of the sculpturing is the work of the wind as it whips the exposed rocks with fine, air-borne particles. In point of fact, wind erosion plays only a small role—though an important one—in the shaping of most landscapes. For a report on this subject, see pages 254-63.

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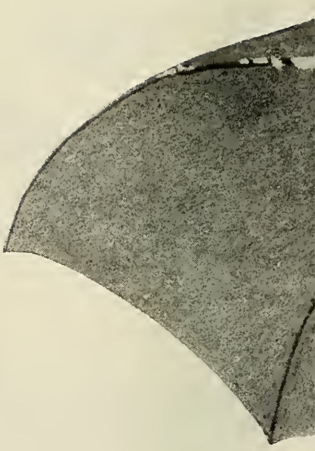
Reviews

By Alvin Novick

HOW BATS FIND THEIR WAY ABOUT



LISTENING IN THE DARK, by Donald R. Griffin. *Yale University Press, $7.50; 413 pp., illustrated.*

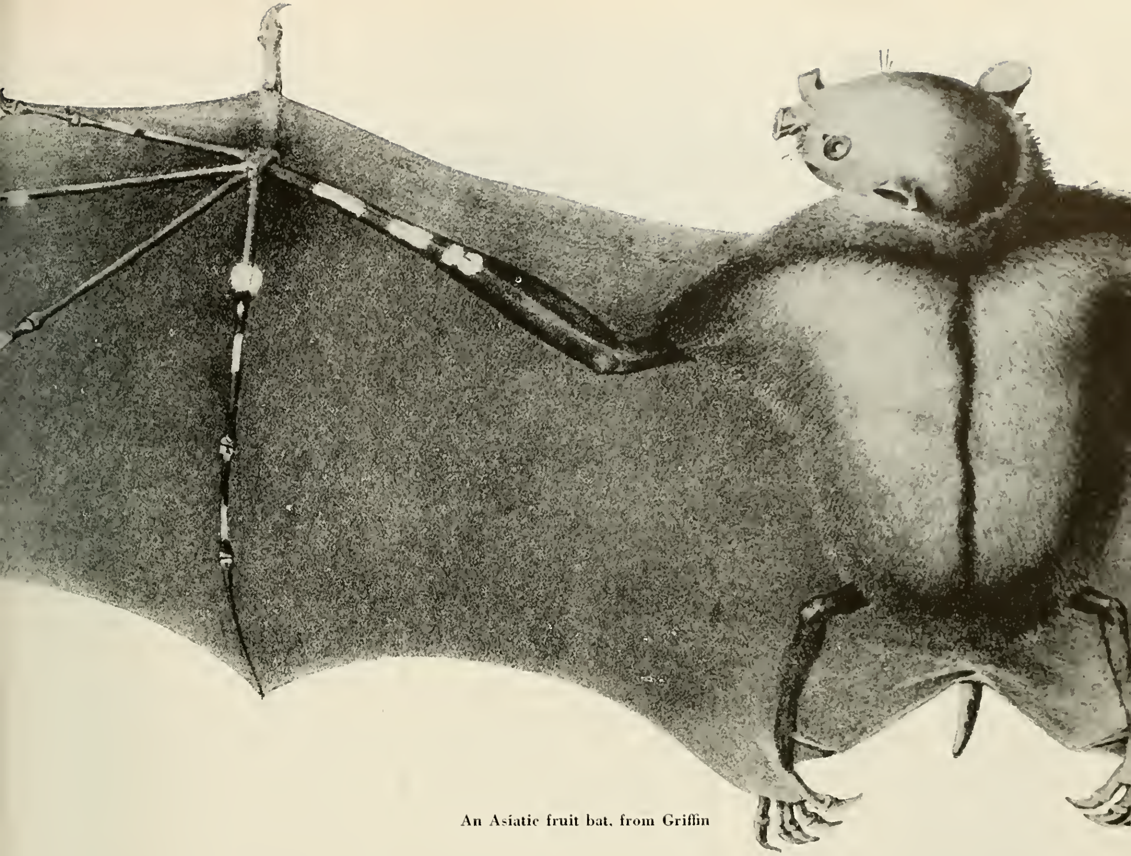
A FEW YEARS BACK, a novel appeared with an albino bat as its heroine. Until now, this unusual book and a number of Charles Addams' brilliant cartoons have made up the bulk of the sympathetic American literature dealing with bats. In Chinese art and folklore, the bat has come to be synonymous with good luck, long life, and happiness; while among the Mexican and Central American Indians the bat played an important part in providing motifs for art—although even there it sometimes took a role that would seem less alien to the American mind, symbolizing death. Our culture, aside from refraining from dealing with bats artistically, insists that one pursue individual, live, intruding bats in a manner calculated to destroy not only the bat and the pursuer's shins but frequently the classic weapons of the chase as well—tennis racket, broom, or baseball bat. In short, bats share the bottom of the animal popularity poll with spiders and snakes. Although they have recently appeared with considerable dramatic effect in *The Bridge on the River Kwai* and as part of the décor of a witch's living room in *Bell, Book, and Candle*, most people continue to regard their dislike and distrust of bats as "instinctive," and perhaps mutual. Few of us can experience the personal evolution from bat-hater to bat-lover that many of Griffin's students (including myself) have enjoyed; but everyone can avail himself of the opportunity to meet bats on their own ground through the eyes and mind of the world's leading student of bats and their sonar.

Griffin is a remarkable man, and in *Listening in the Dark* he has produced a remarkable document. In general, reports of current scientific work are published in one of two forms—the formal, professional paper in a specialty journal, or the all-too-often sensationalized, anecdotal, or cute "humanized" reports in the lay press or magazines. There are, to be sure, a few highly trained science newswriters who report the facts from time to time, but in a manner usually lacking in personal involvement and understanding, one that subverts the living, dynamic quality of science. As a result, the public remains singularly ill-informed about science and scientists, what they do and how, why, where, and when they do it; and celebrates only the occasional great discovery or breakthrough that catches its fancy. At other times, the scientist is patronized. He is fed, clothed, and humored; but he remains, in general, like the bats—mysterious and odd.

GRIFFIN, currently Professor of Zoology at Harvard University, is a physiologist who studies the manner in which animals receive, through their senses, information about the environment. During his career, he has studied homing and migration in birds; but, in *Listening in the Dark*, he describes his discovery and subsequent pursuit of the mechanisms and significance of echolocation in bats. He gives us a personal record of twenty years' work observing bats, caring for them, designing, conducting, and interpreting experiments dealing with their orientation and behavior, and designing and building (or looking forward to building) electronic devices to permit further observations and experiments. But, above all, he gives a brilliantly lucid account of his results to date, as well as a survey of future prospects at the level of pure investigation and general applicability.

As a senior at Harvard, Griffin, already a veteran observer of the natural history of bats and the holder of the world record for bat-banding, first chanced to listen to bats with an instrument built by Professor Pierce for studying insect songs. This fruitful coincidence of Griffin, bats, and Pierce's black box, before long, cleared up one of the perennial mysteries of natural history—how bats find their way around—and eventually led to such anomalies as Griffin's touring the streams of the Panama jungle in a dugout canoe loaded with electronic equipment in pursuit of a fishing bat called *Noctilio.*

IN folklore, for centuries bats have been thought to be blind. Although this is not, strictly speaking, so, there is no evidence that most bats use their eyes for more than perhaps telling night from day. The great Italian physiologist and naturalist, Lazaro Spallanzani, in the 1790's, and his contemporary, Charles Jurine, showed quite clearly that bats' flight and orientation were independent of vision and touch. Though Spallanzani had in fact gathered sufficient data to demonstrate that bats oriented by hearing, this hypothesis eluded him. He clearly and cogently associated bats' ears with orientation—"the ear of the bat serves more efficiently for seeing . . . than do its eyes . . ."—but he failed to recognize that the ears were functioning not in a novel manner but essentially as all mammalian ears do. To conceive of inaudible sound, endowing animals with a sense which could not, at that time, be directly tested or observed, was too great a gap for Spallanzani to span or, perhaps, to dare span. In the nineteenth century, armchair and field naturalists largely ridiculed, ignored, forgot, or did not know of Spallanzani's experiments. Among them, two hypotheses were favored, both wrong—that bats oriented by sensitive touch organs in the wings, nose-leaves, and external ears, or that they possessed a sixth sense. Some may argue that sensitivity to inaudible sound is actually a "sixth" sense, but we ordinarily understand this term to be limited to indefinable, nonphysical, mysterious phenomena not amenable to scientific investigation, such as extrasensory perception or psychokinesis. One



An Asiatic fruit bat, from Griffin

unfortunate scientist singularly distinguished himself in a negative way by saying of Jurine's experiments, "Since bats see with their ears, do they hear with their eyes?"

The problem was resolved when Griffin and a colleague, Robert Galambos, while still graduate students, demonstrated that bats orient by echolocation. The proof involved these main features. Bats were disoriented in flight if their ears were plugged or if their mouths were sealed, but their orientation was not affected by blinding. Sealing their mouths prevented emission of sounds; plugging their ears prevented the reception of sound. Griffin and Galambos were, furthermore, able to pick up and record, for the first time, the high frequency pulses of sound that the bats emitted during flight and upon the echoes of which they depended for information about their environment. Finally, they showed that the bats were capable of perceiving the frequency range of the sound pulses emitted and thus, presumably, able to respond to them. For the general public, this discovery of echolocation or acoustic orientation in bats has become almost historical and surprise is often expressed that investigation should still continue. Griffin deals exhaustively with the nature and purpose of these follow-up studies and, I believe, conveys to the reader the excitement, pleasure, and satisfaction he has gained in bringing forth the complex and beautiful pattern of acoustic orientation in bats.

What are the essentials of echolocation as practiced by bats? By vibrating two pairs of drumhead-like membranes in its larynx, a bat produces a series of ultrasonic pulses of sound which are emitted, depending upon the species, by mouth or nostril. While man hears very little of sound frequencies above eighteen or twenty kilocycles per second—or somewhat more than six octaves above middle C—bats, in general, produce sounds of frequencies largely above twenty kilocycles per second. With some exceptions, these are therefore inaudible to us. In some cases, children, whose ears may be sensitive to frequencies as high as twenty-five kc., hear bats quite plainly (though even they hear only a portion of the nuances present). Several species of bats, on the other hand, routinely produce orientation pulses containing audible frequencies, but the bulk of the sound energy even in these cases appears to be in higher, inaudible, harmonics. Such audible bats, while flying, may sound like a ratchet toy or a high-pitched whistle. Not surprisingly, some mammals, including dogs, have a higher range of frequency sensitivity than we do and may reveal their ability to hear bats' sounds by a visible reaction.

These orientation sounds are of very brief duration, some as short as one-third of a millisecond; the longest are

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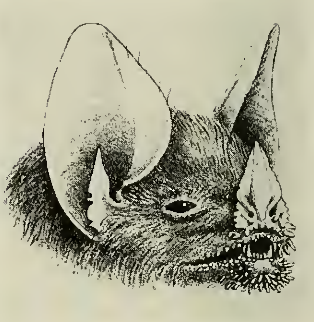
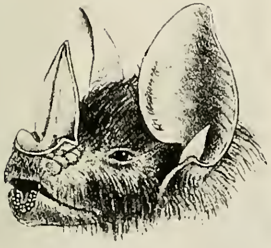
no more than 100 milliseconds or one-tenth of a second. They may be repeated at a rate of perhaps twenty per second, or for brief periods, as high as 250 per second or more. The frequency or frequencies, furthermore, may be varied within individual pulses and successive pulses, and may occur in a variety of frequency and amplitude modulated forms, as well as in harmonic combinations. Depending upon the flight conditions the bat faces, the duration, repetition rate, and rhythm are, indeed, also varied. These sounds, also variable in intensity, are, at least in some cases, directionally beamed.


Trachyops cirrhosus

The pulses of sound, having been emitted, pass through the air in the usual manner of sound at a speed of about 1,100 feet per second and encounter obstructing surfaces in the environment. These surfaces may be, for example, obstacles such as trees or buildings, the ground, flying insect prey, or raindrops. Any such encounter of sound with a surface results in the reflection or scatter of the sound in a manner that depends upon the size, shape, texture, and orientation of the object relative to the sound waves. Some of these reflections or echoes are picked up by the bat's ears, which are frequently large and mobile or of bizarre shape. The signals are then organized and acted upon by the bat's brain, which is largely devoted to areas dealing with acoustic integration.

GRIFFIN deals with additional questions, not necessarily solved as of 1959. When do bats echolocate if, indeed, they do not always do so? Do they avoid obstacles thus, hunt their prey, find their homes and their hunting grounds, migrate thus in fall and spring? What can they measure by echolocation—size, shape, distance, direction, velocity—and how finely and at what range? Can they recognize the total nature of an object? Can they map or recognize a landscape? Granted that they measure some of these things, how do they do so—by the pitch or pitch pattern, timing, loudness, and/or the direction of the echoes, or by yet other qualities or combinations of qualities? Do they integrate successive pulses? How are these sounds designed—in frequency, frequency pattern, intensity, duration, repetition rate, rhythm, and directionality—to suit each particular species? How are they produced, how emitted, how received, how interpreted to maintain the efficiency that the bats display?

BATS, for example, will, with fair success, avoid wires as fine as one-tenth of a millimeter in diameter in a laboratory obstacle course, and some are capable of pursuing and capturing such small insects as fruit flies at a rate of perhaps twenty-five per minute. The statistics representing their best performance are in each case truly astonishing. In producing their sounds, their laryngeal muscles, involved in tensing the vibrating membranes, must presumably contract at a rate of at least 250 times per second in some cases. Yet, such a rate of contraction for mammalian muscle was previously unknown. And in the reception of these sounds, Griffin has shown that the big-eared bat *Plecotus* apparently perceives and responds to echoes of its pulses in a sound field when the echoes or signals are thirty to forty decibels below the noise level. This has proved fascinating and puzzling to radar engineers, who apparently have not yet achieved an equal performance.



Phyllostomus

Many of the questions mentioned above have been answered in the past for vision, the sense which we humans so largely depend upon for orientation, but in studying vision we are helped by our personal knowledge of what we see and how we do so; we can experiment with intelligent and verbal human

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A CRY IN THE NIGHT

Lieutenant Jackson shivered. The harsh Korean winter wind penetrated the thickness of his army overcoat. He held up his hand to protect his face from the biting cold and made a dash for the protection of a wall at the side of the road. As he felt his way along the wall in the darkness, he stumbled over a soft bundle. The bundle moved and a little voice cried out in the night, "Hey, watch out, Mister!"

The bundle that spoke turned out to be a little Korean boy, about 7, who explained that his name was Ho Song and he was huddled against the wall because it was the warmest place he knew in Seoul.

Lieutenant Jackson picked up the youngster and carried him to the camp kitchen. The cook gave him a cup of hot soup and thick slices of bread which the little fellow devoured like a starved animal.

That night, the cook and the Lieutenant put a cot behind the kitchen stove where for the first time in his life, Ho Song slept within warm walls.

In the days that followed, the Lieutenant became fast friends with Ho Song and his little Korean playmates. Inevitably, however, it came time for Lieutenant Jackson to leave Seoul and return to the U.S.A. But his departure did not mean the end of his friendship with Korean children.

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Home in the U.S.A., Lieutenant Jackson and his fiancée arranged to sponsor a Korean child through Save the Children Federation. They found that a little child across the sea would receive supplementary food, warm clothing, new shoes, household articles and some cash through an SCF Sponsorship. And correspondence with the child through SCF meant hope and encouragement.

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subjects and our language is fully expressive in this area. This is not so for sound and especially not so for inaudible sound, where we have no personal capacity and where the available vocabulary is almost trivial.

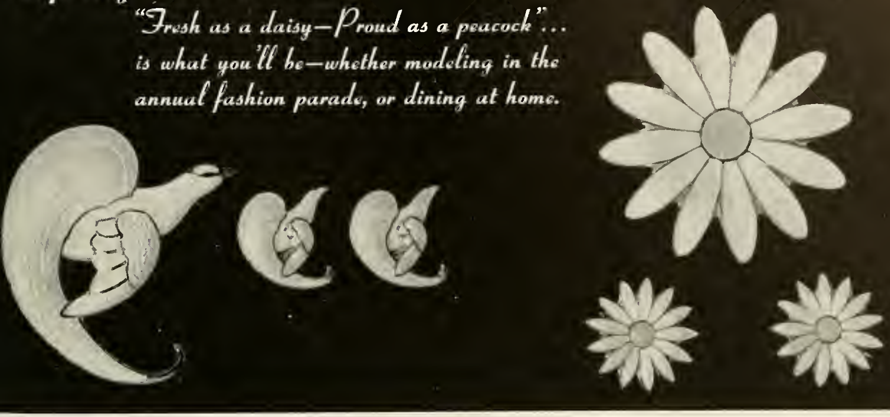
Griffin has overcome many of these obstacles with specially designed or reoriented microphones, loudspeakers, electronic filters, amplifiers, oscillographs and tape recorders with which he has listened to and recorded bat orientation sounds, produced not only in the laboratory but in the field, while the bats were pursuing and capturing their insect prey in full flight. Some of us, in fact, have had memorable experiences when we joined him on his night forays. Several years ago, he was studying red bats as they hunted insects in the course of their August migration south. Griffin's favorite site was adjacent to a miniature golf course in Falmouth, Massachusetts, where we would spend the late evening accoutered with giant pickup horns and all the other paraphernalia associated with our calling. The proprietor of the golf course, who did not mind our taking advantage of his strong lights—which not only attracted insects but permitted us to see the bats as they hunted—asked only that we refrain from telling people what we were doing lest awareness of bats in such close proximity hurt his business. I still treasure the experience of seeing Griffin overcome the obstacle of being accused by various passers-by and golfers and one unusually astute teen-ager of being in turn a flying saucer observer, a Russian spy, an eavesdropper on family secrets, and finally, of all things, a bat man.

GRIFFIN and his students and a handful of European scientists have spread out over the globe to see whether all bats behave similarly. Of the seventeen recognized families of bats, thirteen have now been studied, representing bats of Egypt, Ceylon, the Belgian Congo, Kenya, Mexico, the Philippines, and Panama, in addition to those of Europe and the United States. While most bats feed on flying insects, a number of specialized species have turned to roosting insects, fruit, the pollen, nectar, or petals of flowers, mammalian or avian blood (the true vampires of tropical America), small vertebrates, or fish. For each of these species, the problem of finding and catching its prey is somewhat different.

(continued on page 287)

Spring is in the air...

"Fresh as a daisy—Proud as a peacock"...
is what you'll be—whether modeling in the
annual fashion parade, or dining at home.



Our daisy and peacock pin sets are important accents for the well-dressed woman who chooses her jewelry with care. Norwegian imports, these pieces are made of sterling and then expertly enameled with the finishing touch of a 14 carat gold plate to add to their beauty. Envision a subdued yellow! This is the delicate shade of the tastefully stylized peacock (matching clip-on earrings). We've captured the natural coloring of the daisy and duplicated it in this pin and matching screw-on earrings. Beautifully simple — complimentary to all.

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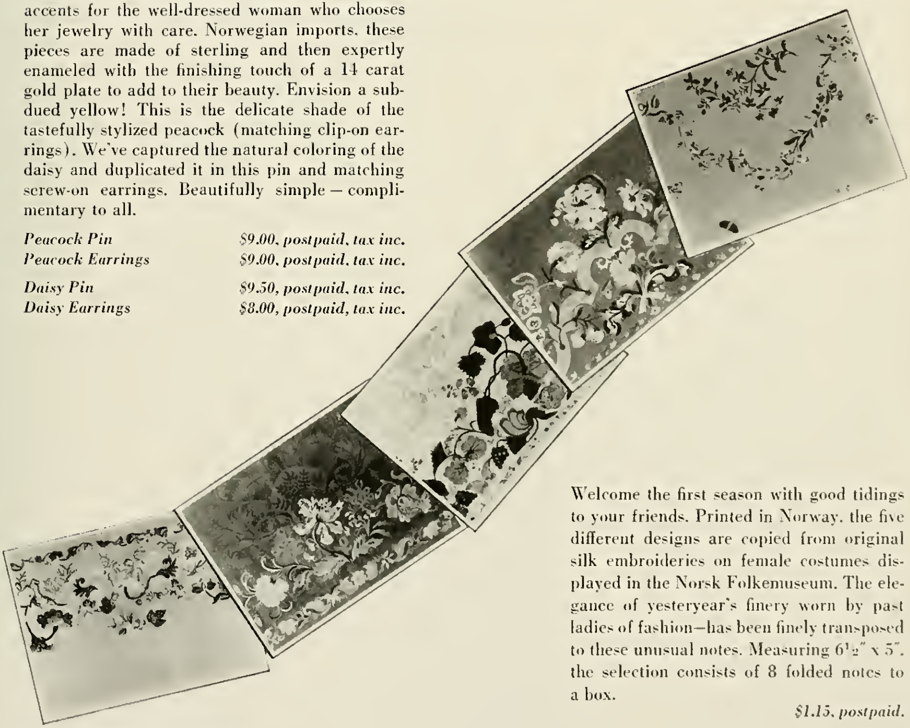

Welcome the first season with good tidings to your friends. Printed in Norway, the five different designs are copied from original silk embroideries on female costumes displayed in the Norsk Folkemuseum. The elegance of yesteryear's finery worn by past ladies of fashion—has been finely transposed to these unusual notes. Measuring $6\frac{1}{2}$" x 5", the selection consists of 8 folded notes to a box.

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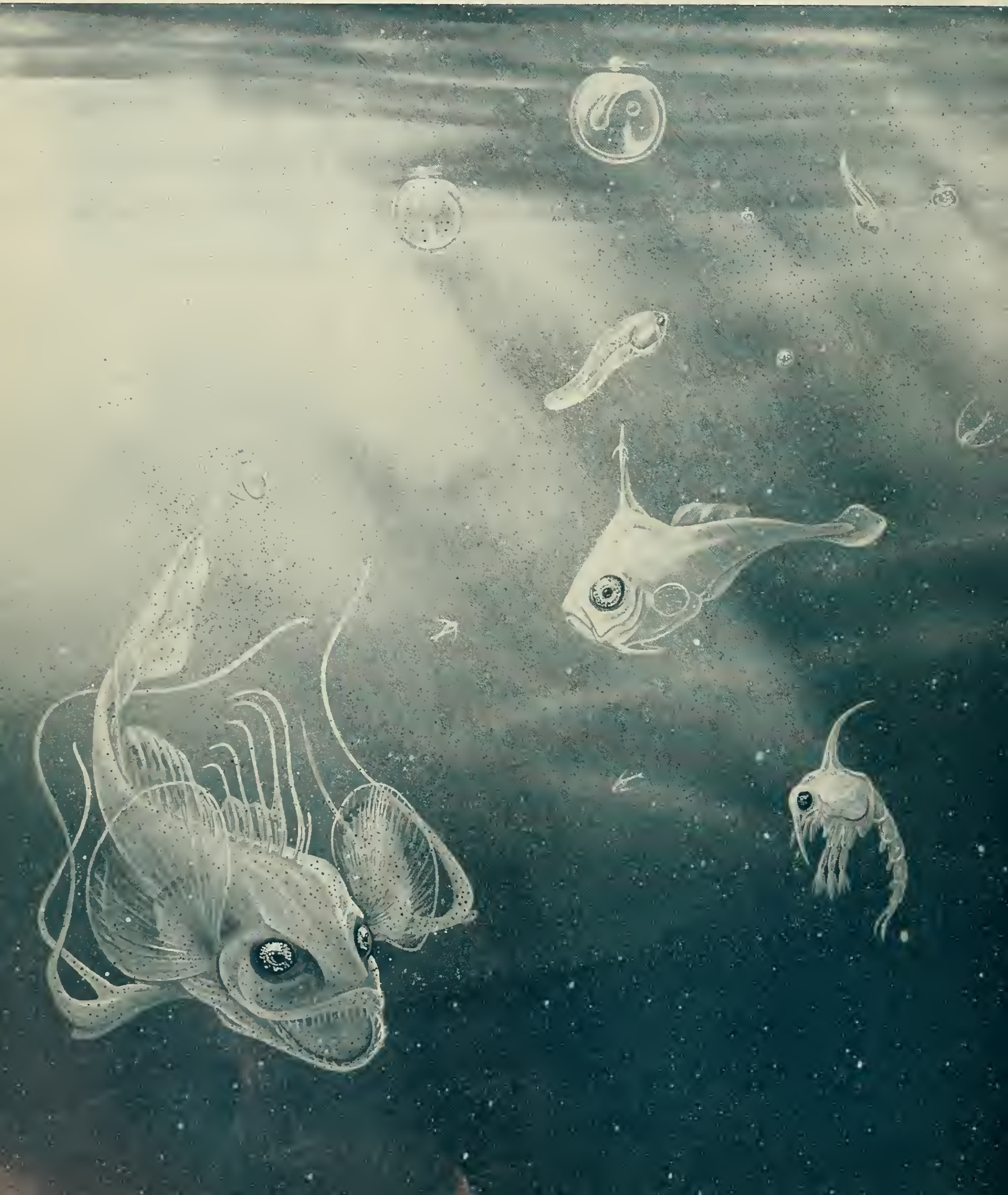
Wanderers of



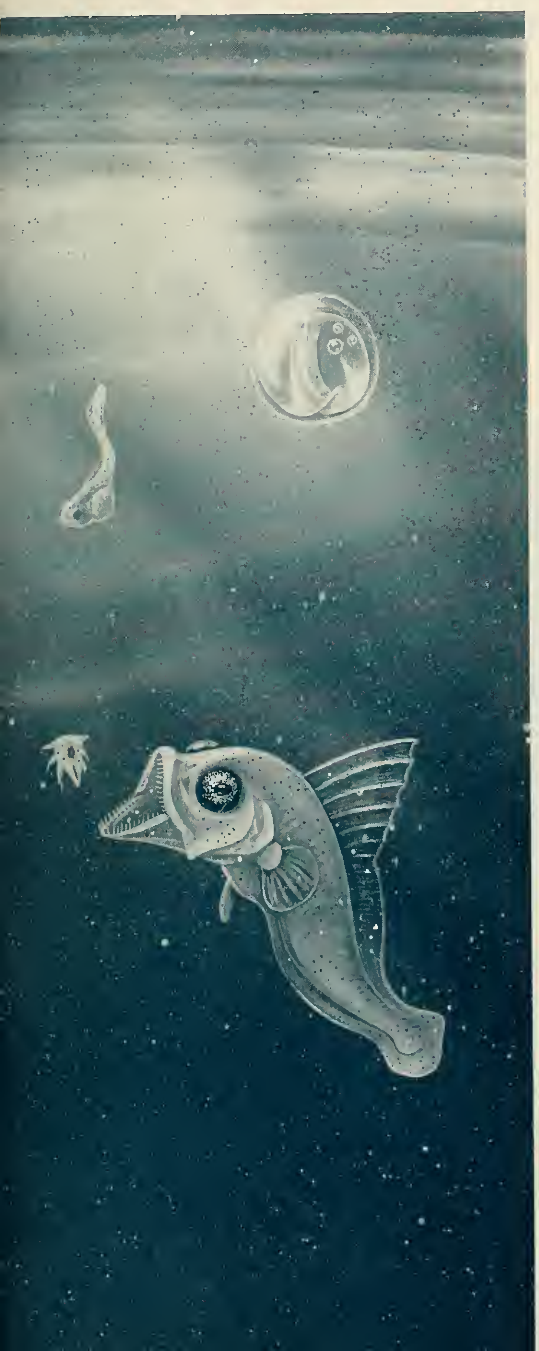
Floating eggs, buoyed up by tiny oil drops in the yolks, are but a few days old. Prolarvae, near top, can seldom be identified — specialization comes with feeding, as shown in angler fish, *left*, filefish, *center*, and mackerel, *right*.

the Ocean

Known collectively as plankton, they range from plants to fish

By William N. Tavolga

Illustrations by Kenneth Gosner



PLANKTON is the collective term (from the Greek *planktos*: wandering) that marine biologists use for the minute, often microscopic, plant and animal life that floats and swims throughout the marvelously complex, salty soup that makes up our oceans. The plant portion of this mixture—or the phytoplankton—is composed mostly of single-celled algae and bacteria. The animal fraction—the zooplankton—consists primarily of protozoa, of tiny, insect-like crustacea and, finally, of fish in their early, developmental stages. This last component, the fish larvae, is the only one to represent the higher, vertebrate forms of life. It is also in many ways the most remarkable. Although these larval fishes spend only a brief portion of their life as members of the planktonic community, they are—during this short chapter of their lives—as highly specialized in form and behavior as they are destined to become, in adult form, for their adult, pelagic environment.

The vast majority of salt-water fishes pass through a planktonic, floating, larval stage. In terms of survival of the species, the advantage of such a life-stage is that the great multitudes produced not only enhance survival chances by sheer weight of numbers but also favor an ever-widening dispersal of the species. Planktonic fish larvae are small and delicate. Some few reach an inch or two in size, but most are less than a quarter of an inch in length: all are thin, and so transparent as to seem ethereal.

Not all the planktonic fishes join the community as larvae: many also spend their embryonic life afloat. Small, transparent, fish eggs form a significant portion of the zooplankton, floating upward to the surface from point of deposition with the aid of a drop of light oil within each egg. Such eggs develop rapidly and many will hatch within a few days or a week of release and fertilization. These newly hatched larvae, often called "prolarvae," are frequently nothing more than advanced embryos: each possesses a small head with primordial eyes, a bluntly rounded tail capable only of slow twitching, and a large sac of glassy-clear yolk, still containing its buoyant drop of oil. At the prolarva stage, there is very little diversity among many species of fishes—even between distantly related fish. The differences that can be seen are of a superficial nature: i.e., relative length of tail, size of eye, size of yolk, distribution of starlike pigment cells, number of muscle segments, and a few variations in proportions.

SUCH basic similarities in prolarvae make it difficult to discriminate between species and, in many cases, identifications are matters of guesswork. These similarities also indicate the fundamental relationship of all the bony fishes (teleosts) and are evidence of their descent from a common ancestral form. The comparative anatomists and embryologists of the nineteenth century ad-

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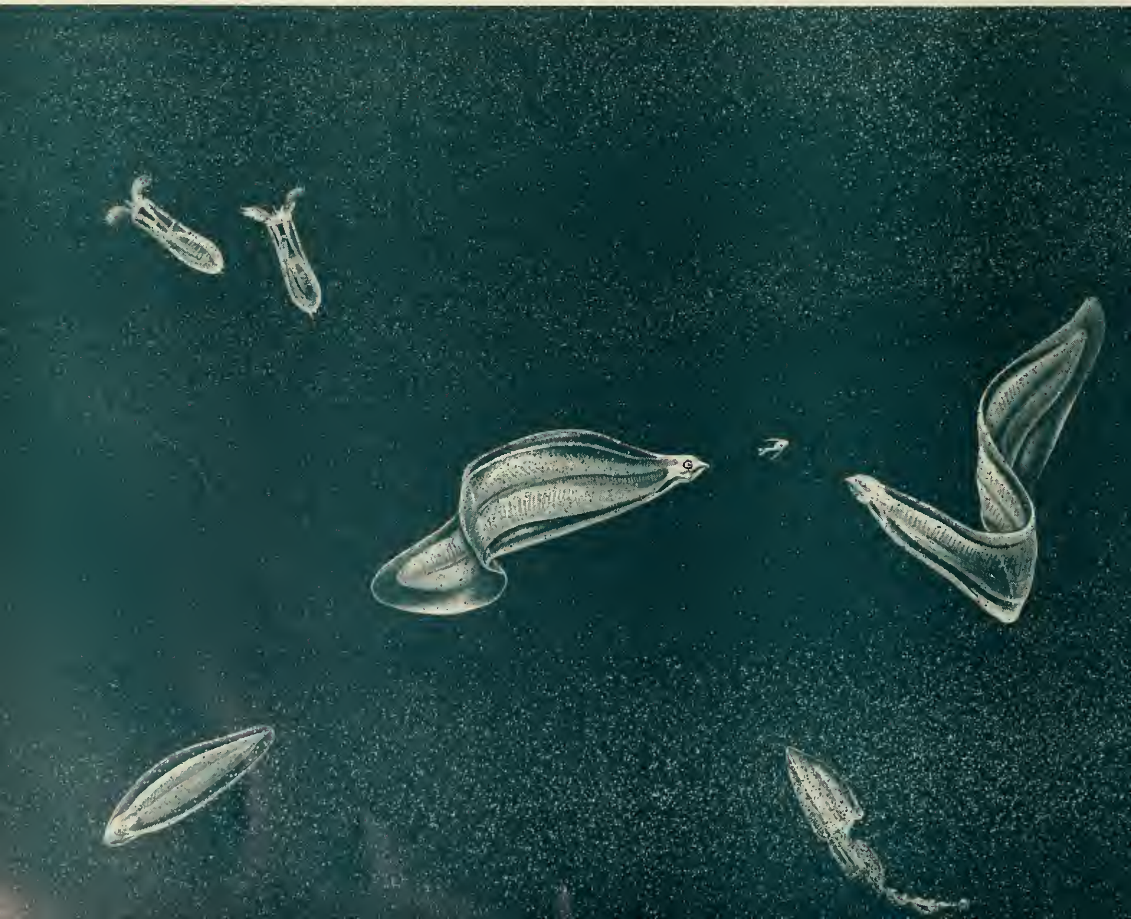
hered closely to a biological principle known variously as Haeckel's Law (after Ernst Haeckel, 1834-1919), the biogenetic law, or the law of recapitulation. This stated that all organisms recapitulate their evolutionary ancestry during the course of their embryonic development. Thus, at various points along the continuum of growth from egg to maturity, according to Haeckel's Law, the organism shows resemblances to ancestral, extinct forms—running the gamut from the most ancient and primitive to the recent and advanced. In a very broad sense, this principle is well supported by evidence—such as a tadpole's resemblance to the fishlike ancestors of frogs; the gill slits possessed by mammalian embryos at certain stages; the tails displayed by human embryos; and the similarity of the embryos and pelagic prolarval stages of the marine fishes.

Upon closer scrutiny, however, Haeckel's Law begins to break down. There is not now, nor has there ever been an amphibian ancestor that looked exactly like a tadpole: nor are the gill slits of a mammalian embryo ever functional; they are quite different in form from those of their fishlike predecessors. Similarly, the prolarva stage of fishes is *not* represented in the ancestral record as the specific form from which all modern bony fishes have arisen. This does not mean, of course, that the biogenetic law has no validity: the principle remains a useful guide to the study of evolutionary relationships.

But it must be remembered that, during the course of evolutionary progress, there have been specializations and changes at all time levels of the organism. Developmental short cuts have appeared to mask and alter the ancestral forms. Embryos may be just as highly specialized for their environment as are adults. A prime example of such embryonic specialization is to be found among viviparous animals. Both the guppy and man are liveborn, and each shows specific adaptations for a parasitic survival within the mother by drawing nourishment from her blood fluids.

The prolarva itself shows some specializations for survival as a planktonic organism. Its very small size and its physiological adaptation to sea water enables it to live through the critical transition—from the depletion of its nourishing yolk to the stage at which it begins to catch its own food. The metamorphosis of the prolarva begins with the acquisition of a mouth, which starts to function about the time the yolk supply is exhausted. The larva is now entirely on its own: equipped with large, well-functioning jaws, set with microscopic teeth, but it is not particularly



mobile. At this stage, most larvae are voracious predators, however: they snap energetically, albeit often ineffectually, at any floating object in their vicinity. Should the object prove to be of the right size, digestible and nutritious—and if it does not get away—then the larva will have gained enough food to keep it growing until its next lucky snap.

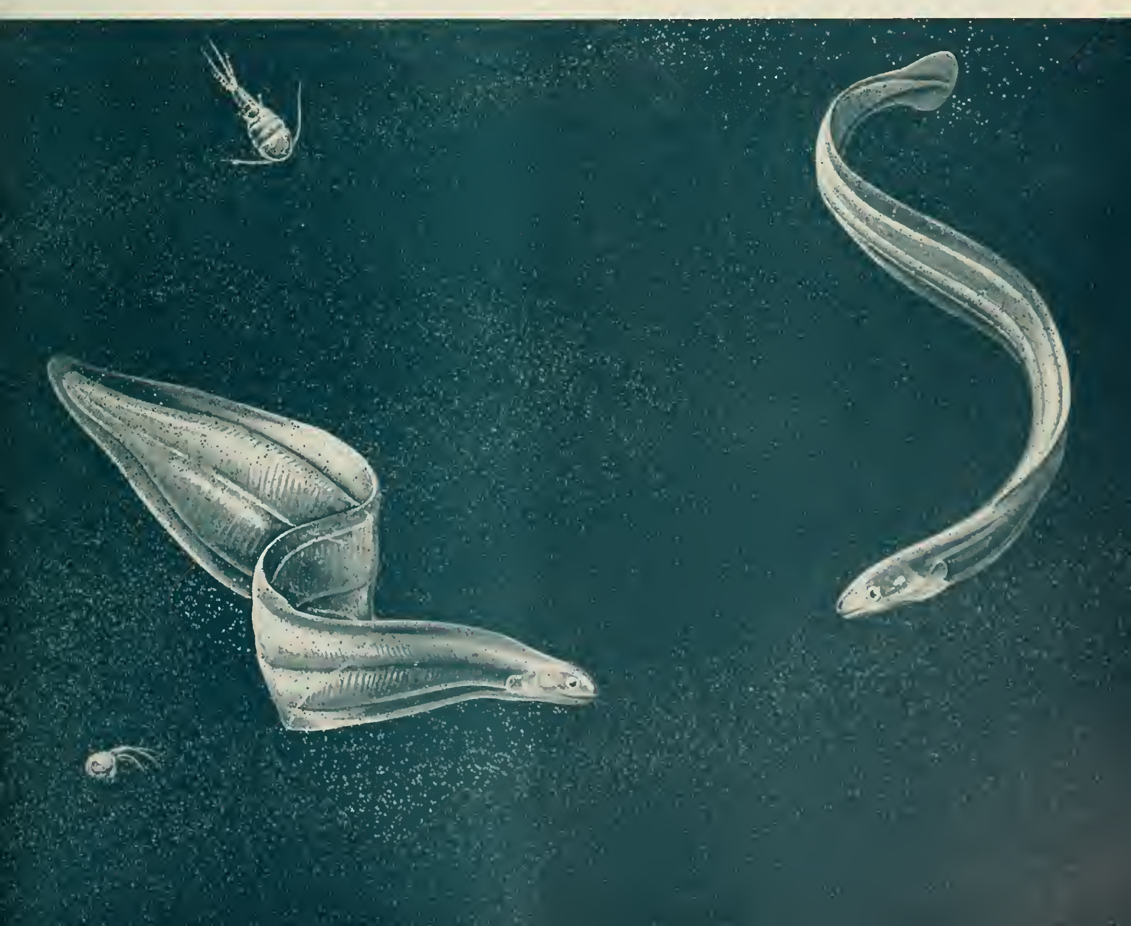
Few larvae are good swimmers, and many simply float passively in the water. Their small size and unsubstantial construction tend to keep them afloat. Small drops of oil and trapped bubbles of air assist their upward drift. It is at this stage that the greatest diversity of forms exists. The larvae of different species are as unlike each other as are the adults, and each species has its unique adaptations for survival as part of the plankton.

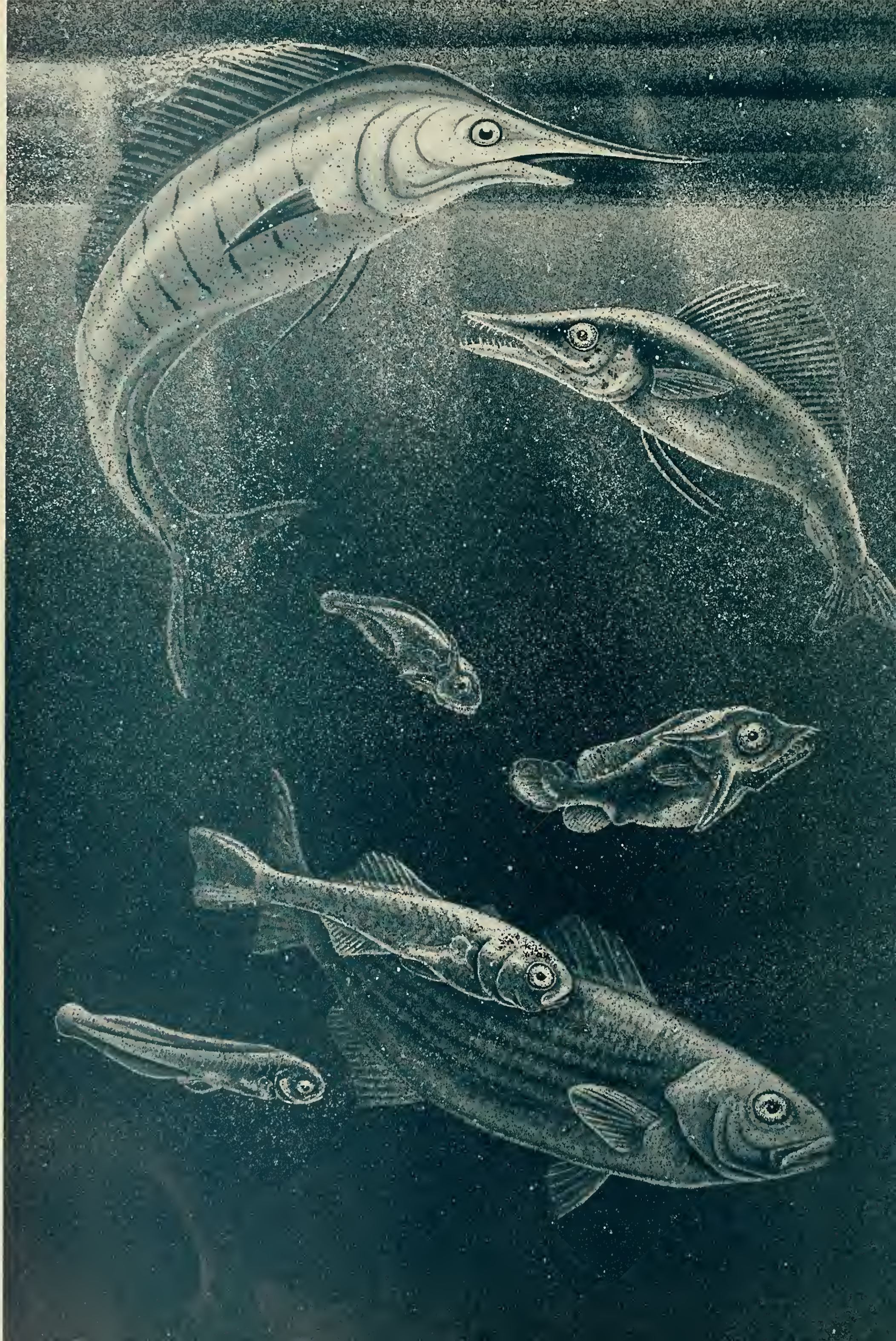
Many species possess long streaming extensions of the fins and other body parts. Such prolongations increase the total effective surface area of the animal and greatly enhance its buoyancy and response to the slightest movement of the water. The long threadlike appendages of the angler fish larva, and some of the deep-sea types, are good examples of such specializations.

Some species actually pass through a sequence of several larval stages, with a new form and specialization at each successive stage. Newly hatched eel prolarvae are less than ten millimeters in length: quite narrow in proportion, but otherwise like the majority of primitive, floating embryos. With little change in total length, their jaws develop first into a pair of fierce-looking toothed pincers. Next, these change into something resembling a pair of hay rakes. Such structures are obviously specialized for some particular type of planktonic food, but the exact nature of the eel larva's food and feeding habits is completely unknown.

As the eel larva grows larger, the head begins to take on a more familiar and usual appearance, but a remarkable change occurs in the body form. By the time it has attained a length of about five inches, its body is compressed into a thin ribbon with the transparency of cellophane. In normal light, all that one can see of this leptocephalus larva are a pair of small black eyes—the body is quite invisible. By careful manipulation of light beams, it is possible to see occasional flashes of iridescence: these iridescent reflections come from the edges of the V-shaped bands of muscles that comprise the body. The next metamorphosis brings a decrease in length but, this time, the animal takes on the final form of an eel. It retains its glassy transparency, however, for some time longer. An even more

Development of eel shows progression of a larva through leptocephalus stage to glass eel. Five-inch form at far right has an eel's normal shape, although it remains transparent.





remarkable feature of eel development is the fact that this metamorphosis from prolarva. through leptocephalus, to glass eel, takes place en route from the spawning areas.

Both the American and European populations of Atlantic eels spawn in that vague portion of the Atlantic Ocean known as the Sargasso Sea. As adults, however, they spend their lives in estuaries, rivers, and other inland, fresh-water areas. After sexual maturity, they migrate back to their mid-Atlantic place of origin to reproduce. Until the early 1900's, the spawning areas of eels were a complete mystery but, by patient collecting and research, the various stages were pieced together. Today, problems still remain. How do the larval forms find their way through hundreds of miles of ocean to fresh water? How do they find their way back as adults? Why do not the American and European populations get mixed? Do they follow deep ocean currents? What sensory cues direct their journey? Calling this migratory movement "instinctive" simply begs the question. Continuing studies of the structural and physiological development of the eel larvae may someday provide answers, but, as we shall see here, there are many more problems associated with larval growth of bony fishes.

How are such virtually transparent—as well as extremely small—life-forms obtained for study? Planktonic fish larvae are collected with a long, conical net of extremely fine, silk mesh. This net, fitted with a small jar at its apex, is usually dragged slowly through the water behind a boat at various depths. The size of the nets and the fineness of their mesh vary with the type of organisms sought. The majority of planktonic organisms—and especially larval fishes—are extremely delicate and fragile: most of them are dead by the time the contents of the collecting jar are examined. The few specimens that remain alive after the rigors of collection rarely survive under laboratory conditions for more than a few hours. All the metamorphoses, related here, therefore, have not been observed directly but pieced together through the painstaking accumulation and study of series of specimens at different stages. In some cases, it has taken many years and thousands of collections to reconstruct the developmental sequence of a single species of fish. For example, that commonplace of the textbooks—the metamorphosis of the flounder and the way in which one eye migrates from one side of the head to the other—has never actually been seen as a complete process in a single specimen. But the changes have been assembled in so step-by-step a fashion that a motion picture could be made by using different specimens for each frame.

A REMARKABLE instance of this sort of reconstruction—including the hypothetical deduction of missing elements—involves the life history of a deep-sea fish known as the "gleaming-tailed sea dragon" *(Idiacanthus)*. About sixty years ago, some collections of plankton—from depths of about a hundred fathoms in the North Atlantic—brought to light a most unusual kind of fish larva. The specimens were about 25 millimeters long and eel-like in body form, with a large duckbill snout. But the eyes were set out at the ends of long, thin stalks. The eye-stalks were almost half as long as the larva's body and possessed a core of flexible cartilage for support. The specimens were obviously larval forms, but the adult of this species could not even be imagined. They were formally given the scientific name, *Stylophthalmus*, which means "eyes like pillars."

In 1934, the explorer-naturalist William Beebe demonstrated that the stalk-eyed monstrosity was in reality the larval form of a deep-sea fish known as *Idiacanthus*. The adults of *Idiacanthus*, although rare, have been known for over a hundred years. Small, snakelike fish, rarely over eight inches in length, they are characterized by tremendously enlarged jaws. They also possess some luminous organs on the body, but their large eyes are set in sockets in the normal manner. In a collection of plankton taken at depths of from 500 to 1,000 fathoms in the vicinity of Bermuda, Dr. Beebe found not only *Idiacanthus* adults, but also intermediate larval stages—going back in development to the stalk-eyed form. He found that, during development, the optic nerves shorten and pull the eyes back into their sockets. The cartilaginous stalk gradually becomes jammed into a twisted coil and eventually atrophies.

GAME FISH developments are seen in snout and fin changes of a sailfish, *above*, and in a striped bass, *below*. The bass shows a much less striking and specialized metamorphosis.

THE complete life histories of many marine fishes remain unknown. In an average collection of plankton, one can usually find a number of eggs and larvae whose later developmental fate is a complete mystery. This is particularly true for the very young prolarvae in which few or no differences between species (and even between families and orders of fishes) are detectable. There are also many fishes, well known as adults, whose larval life history is unknown. The famous game fish, the tarpon, is one of these: until recently, the youngest known tarpon were slightly under two inches in length—at that stage, their general body shape and proportions are much like those of an adult. This stage, then, is postlarval.

In February of last year, Dr. Robert Harrington, working with the Florida State Board of Health, described tarpon larvae of about three-quarters of an inch in length. This discovery has cut down the extent of the tarpon mystery substantially. However, while it is thought that the tarpon passes through a leptocephalus stage, this form has not yet been identified and the tarpon's earlier larval history is still unknown.

One obvious approach to closing these gaps in our knowledge would be to raise marine fish eggs and larvae to maturity, or at least to a postlarval state, in the aquarium, where changes could be continuously observed. The obvious, however, is fraught with difficulties. In recent years, Dr. Robert W. Morris, of the Hopkins Marine Station in California, has made some distinct advances in rearing marine fishes. There is a critical period in the life of the larva — when its yolk begins to be used up and it switches to feeding by mouth. The greatest mortality appears to occur at this point. But this is not the only hazard that must be surmounted. The larva is unable to withstand the smallest environmental changes—changes in temperature, salinity, acidity, aeration and light. The larva's tolerance to different types of food and various bacterial invasions is also very low: although a variety of materials will actually be ingested, most prove to be toxic or, at best, indigestible. The abundance, as well as the quality, of food must be controlled: oversupply can be just as fatal as undernourishment. Physical conditions approximating a planktonic environment are essential: a certain amount of water movement must be maintained—but not too much, for bumping into solid objects or over-crowding must be avoided. Minute traces of foreign substances from aquarium walls may prove poisonous; on the other hand, certain trace chemicals turn out to be essential for growth and survival. To magnify the problem still more, the requirements of each species are often slightly different. One wonders how any fish larvae survive.

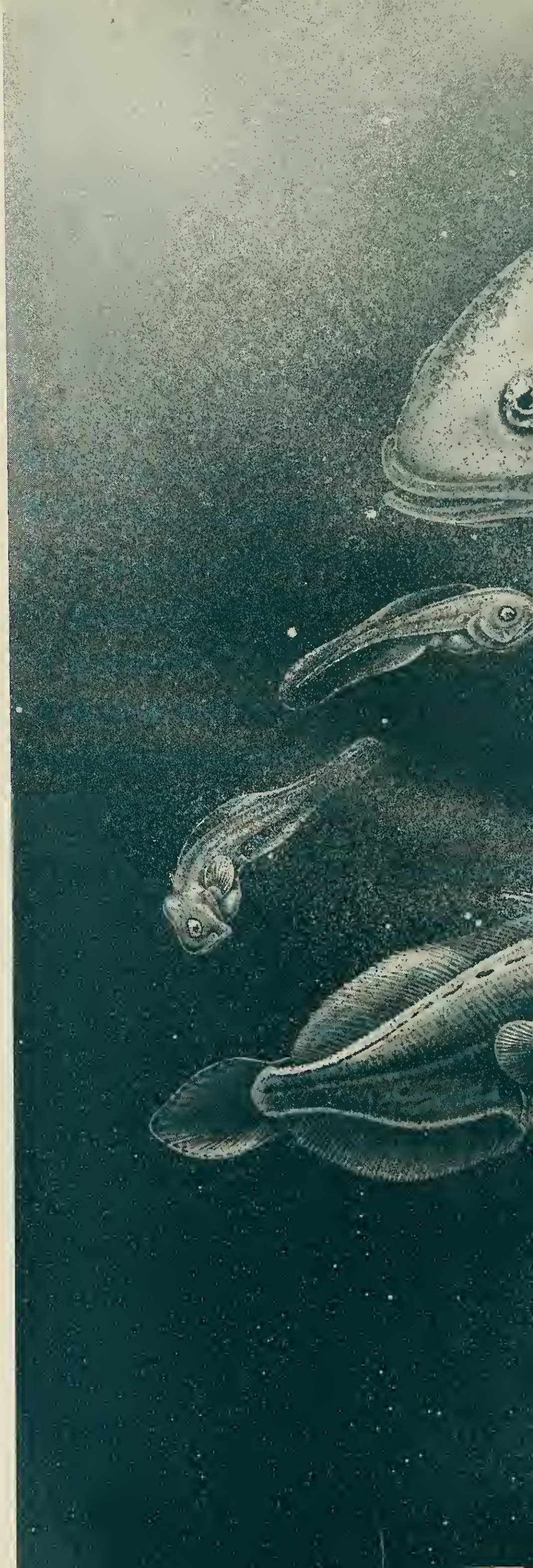
SUCH STUDIES as Dr. Morris' make it increasingly clear that the sea is not simply, as first described, a salty soup: it contains as many or more localized micro-environments as does the forest ashore, with its variety of environmental niches. Each fish species finds its own niche—not by seeking it, but by tumbling into it by chance. The narrow limits within which fish larvae survive means, of course, that vast numbers die. But vaster numbers, of course, are born. And the unsuccessful serve their own role.

An average female goby (*see* "A Tidal Zone Resident," NATURAL HISTORY, March, 1958) will produce up to 200,000 eggs a year. This is probably about average for the output of most marine fishes, but it pales in comparison to even the common codfish, whose offspring number in the millions. Obviously, in order to be so prolific, the structure of the individual egg and larva must be as simple as possible, provided with the minimum of stored food, and the minimum of defensive mechanisms. The very simplicity of structure cuts the chances of survival for any one larva to a low probability: one in a hundred thousand, or even as little as one in a million.

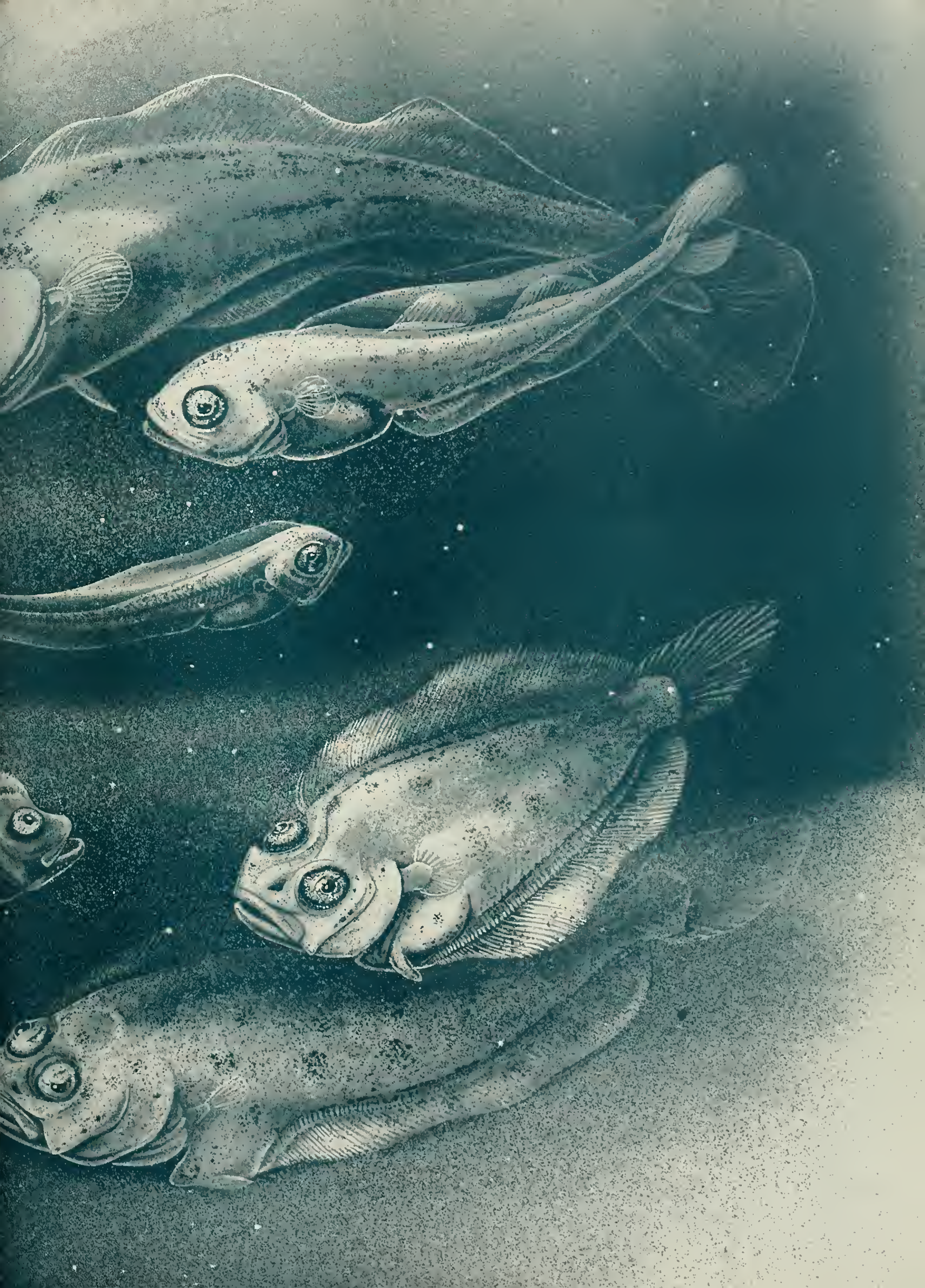
For those that survive, there is a gradual growth in size and a change in the larva's form. Slowly, the larva loses its planktonic morphology and assumes the shape of the adult fish in miniature. Eventually, the particular environmental niche of the species is found and the larva now becomes a small fish, called a postlarva or "fry."

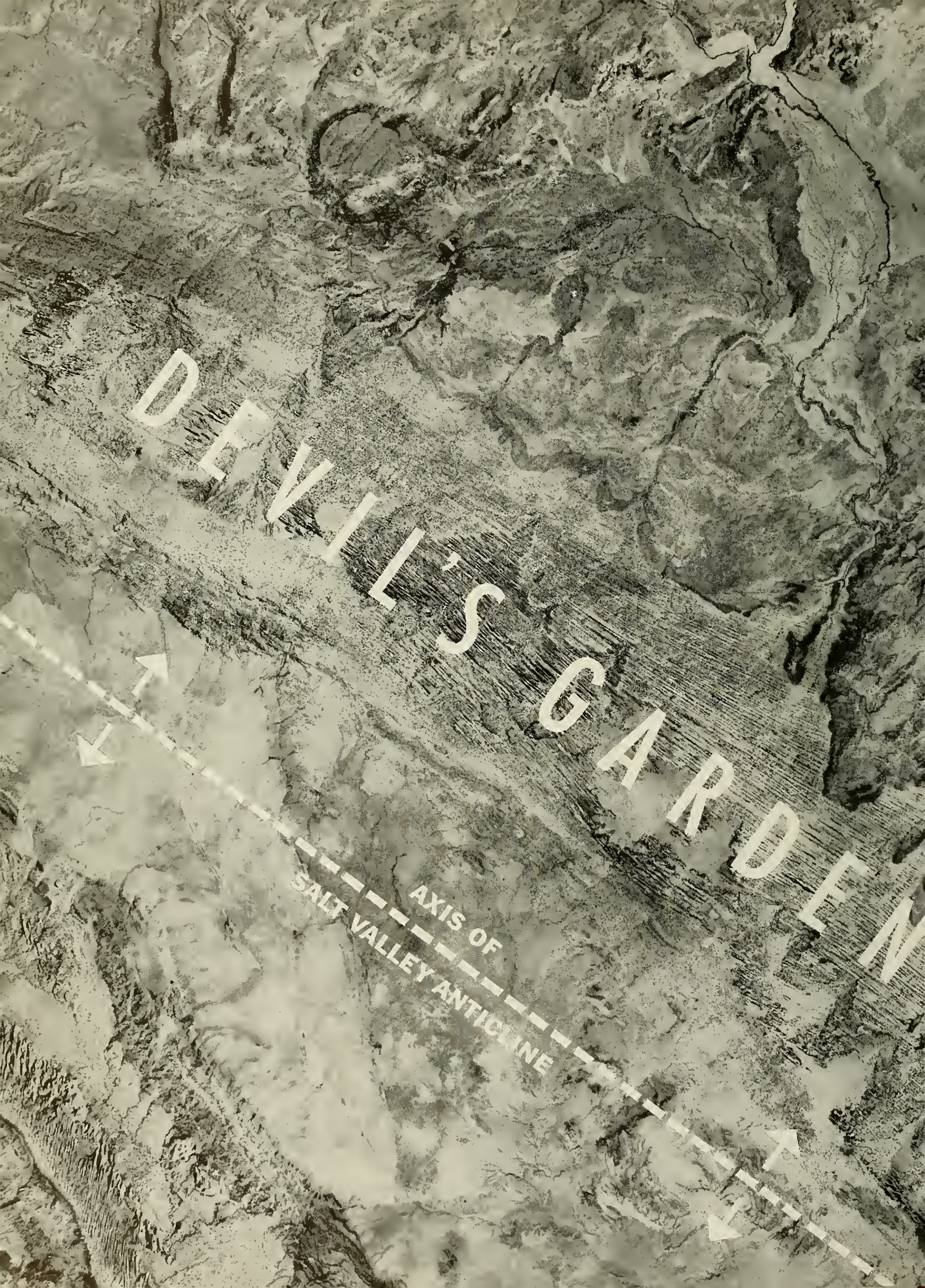
The element of chance plays a great role in the successful survival of a given individual. The delicate and helpless larvae are completely at the mercy of water currents and chance encounters with larger predators possessing bigger jaws. Even getting the proper food is largely a matter of luck. Plankton as a whole, including the fish larvae, forms the basic food for all the oceans' inhabitants. The smallest and the largest of the marine vertebrates feed directly upon the microscopic particles of life. The main food of larval fishes consists of other larval forms and of microscopic algae: on a larger scale, the giant whale shark, the manta ray, and the baleen whale act as great floating sieves, straining the living plankton from the sea.

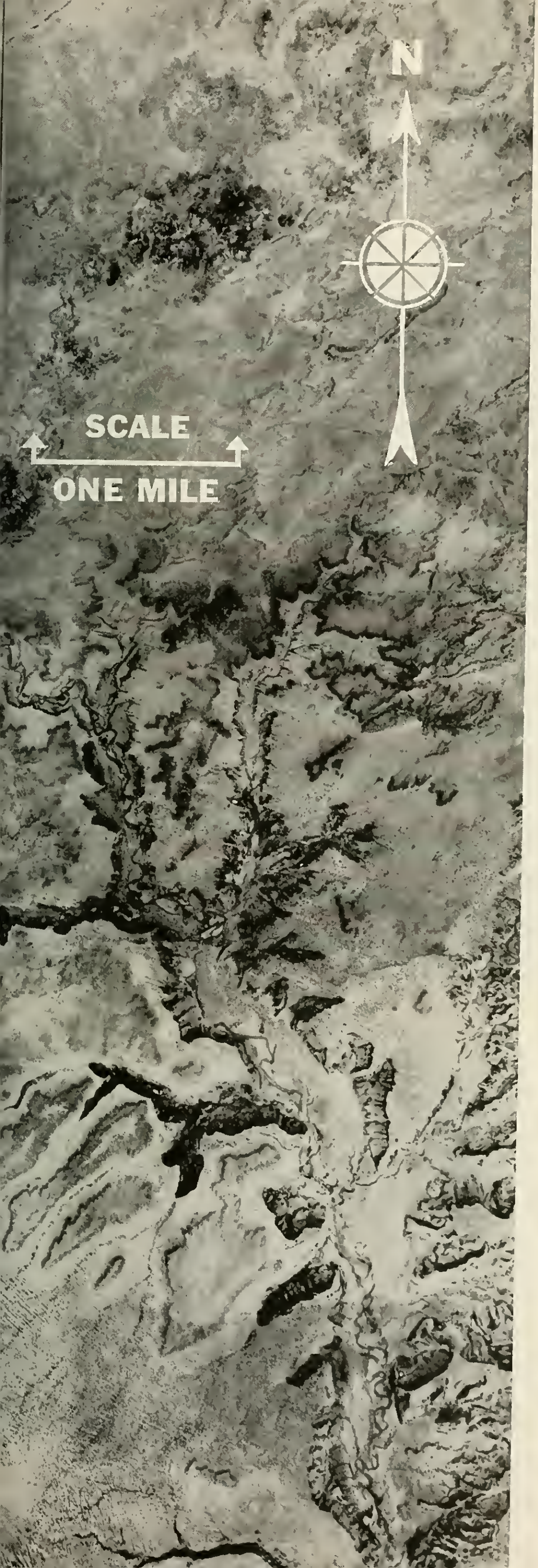
The abundance of planktonic fishes far exceeds the demand, and it is probable that only a small fraction of the total is actually eaten directly by predators or plankton-grazers. The majority who do not survive contribute to the life of the oceans' organisms of decomposition and decay—the bacteria. The cycle of reincarnation is continuous, and the bacteria can become part of a fish again, which, when it dies, can return its organic components to other forms of life. Through all this re-cycling, the algal component of the plankton keeps replenishing the supply of organic materials in the sea by its unique ability for photosynthesis. Thus, while the whale eats the larvae, the larvae also eat the whale.

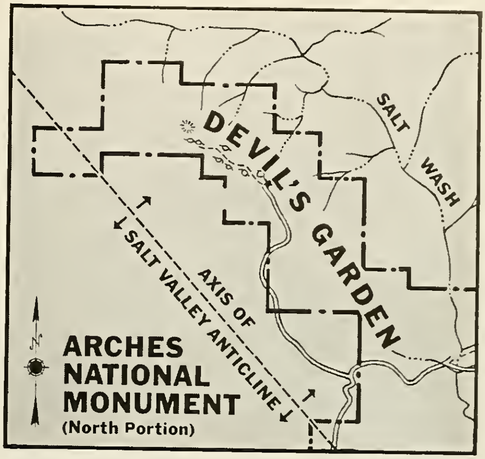


FOOD FISH metamorphosis is shown as codfish, *above*, grows from prolarval to juvenile stage. *Below*, a flounder flattens laterally, while right eye migrates to left side of its head.




DEVIL'S GARDEN
AXIS OF
SALT VALLEY ANTICLINE





DEVIL'S GARDEN, a feature of Arches National Monument in Utah, *above*, is the striated, diagonal zone in the aerial photograph, *opposite*. This prominent joint pattern guides the erosion and arch development in the massive formation.

THE WIND AT WORK

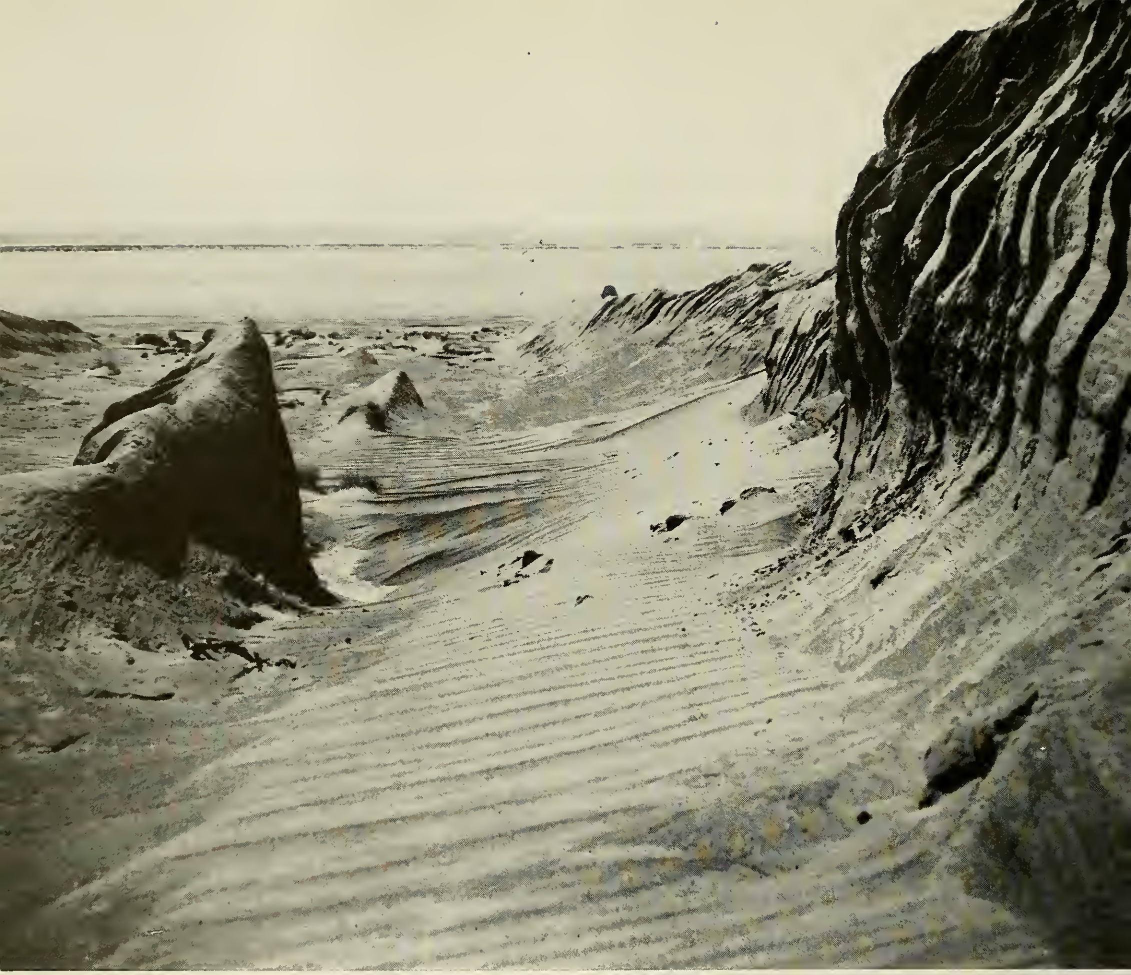
The powers of wind erosion are less than is commonly supposed

By Richard L. Threet

EVERYWHERE ON THE FACE OF THE EARTH, the wind blows almost incessantly, sweeping loose objects along and hurling sand or dust violently against anything in its path. Perhaps by analogy to artificial sandblasting, the wind has sometimes been given credit as a major agent in the erosional shaping of landscapes. Various natural arch formations, pedestal rocks, honeycomb fretwork, balanced rocks, pinnacles, and even vast desert basins have been ascribed to the erosional work of abrasive-laden winds.

Unlike this questionable erosional power, the depositional activities of the wind are well known. They are often responsible for spectacular landscapes of shifting sand dunes, and even the strange dunelike mounds of curled clay flakes, derived from desiccated flood-plain lakes of the lower Rio Grande. Much has been written on the aerodynamics of dune formation and transportation of sand, but little is known about the ways in which winds work to erode solid rock.

These erosional processes seem to be of two types: (1)



Wind-scoured trough, in the Mojave Desert of California, is flanked at left and right by a pair of yardangs, sharp formations carved by the abrasion of wind-borne particles from the ancient clays and silts of the former lake bottom.

abrasion, a scouring and polishing of solid rock by grit-laden wind; and (2) *deflation*, the blowing away of loose rock and soil particles which lie at the earth's surface. There can be no doubt that the former of these processes, wind abrasion, is effective—at least on a small scale. Telephone poles have been sawed off at ground level by blowing sand in desert regions, and automobile windows have become completely frosted during a single sandstorm. Grooves and pits have been cut into boulders exposed to blowing sand; *Dreikanter* (German for "three-edges," see illustrations, *right*), and polished pebbles faceted like Brazil nuts attest to the cutting power of abrasive-laden wind in the desert, along beaches, or on

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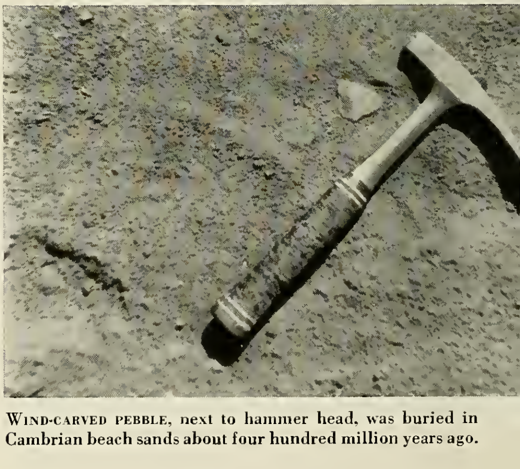
Professor Threet, a geologist at the University of Utah, here applies his special interest in the development of landscapes to the formations in Arches National Monument.



Wind-carved pebble, next to hammer head, was buried in Cambrian beach sands about four hundred million years ago.

sand bars. The curiously grooved and fluted banks of clay—known as yardangs, a name given them in Chinese Turkestan—found in the Middle East and other desert areas have surely been carved by swirling sand and dust. Whether such natural sandblast has played an important part in producing large features—like pedestal rocks and arches—in consolidated rock, however, is another matter.

As the wind streams over the landscape, it is generally at a serious disadvantage in abrasion of hard, rocky surfaces, because the strongest winds are usually found high above the ground. Only where the air is funneled through local constrictions will the velocity of wind-driven particles be high enough for significant abrasion.

On the other hand, the flow of air at the earth's surface is generally turbulent, sucking up loose particles of rock into the stronger currents and carrying them for considerable distances. Because large and heavy rock fragments settle rapidly, usually only fine sand and dust rise more than a few inches off the ground, even in very severe windstorms. Rock fragments more than one or two inches in diameter are seldom moved by wind but often are left behind as a "desert pavement"—which armors and temporarily protects the underlying stones and soil from further removal. This cover may be further strengthened, temporarily, by the deposition of thin films of "desert varnish"—minute quantities of manganese and iron oxides, literally "sweated" out of the soil and pebbles and left behind as the moisture evaporates into the dry air. No rocks, however, are capable of long withstanding the onslaught of physical and chemical weathering. The finer, fragmental products of weathering, as well as the salty, crystalline residues of chemical alteration, may be carried away easily by wind action, or by rainwash and other gravity-induced movements.

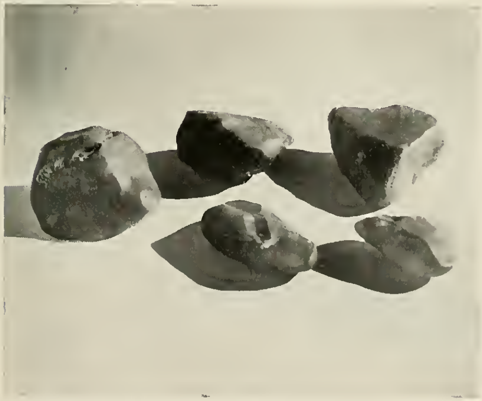
The deflational capabilities of the wind are truly phenomenal. It has been estimated that the transporting capacity of the atmosphere moving above the Mississippi Valley is a thousand times as great as that of the rivers below. During the drought years of the 1930's, the winds picked up vast clouds of loose and unprotected topsoil from the western Great Plains and sifted a gritty film of dust over most of the eastern United States.

One severe dust storm — in May, 1935 — dumped an estimated 101 *tons* of dust per square mile, on areas as distant as Washington, D. C. (with the dust content of only the *lower* one mile of atmosphere considered in the calculation). In the eastern Great Plains, nearer the source, the dust clouds extended to altitudes of two miles and more, plunging the area into total darkness at midday. At the University of Nebraska, Professor A. L. Lugn caught samples of the settled dust on strategically located sheets of paper; from the average weight of these aliquot portions, he computed that the equivalent of forty train *carloads* of dust—or some 1,600 tons—fell per square mile.

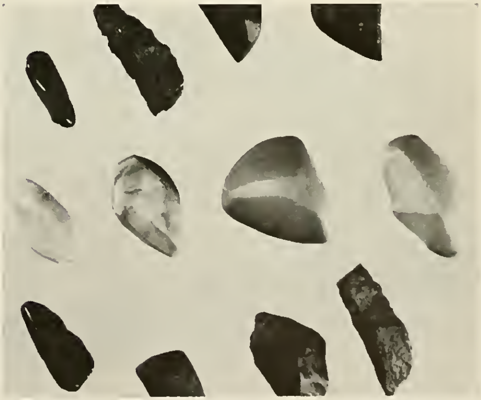
In the source areas, wind deflation may lower the land surface by a matter of several inches or even a few feet in a comparatively short time. On the Nile Delta, it is estimated that deflation has lowered the surface as much as seven feet in the past 2,600 years. Professor Eliot Blackwelder, of Stanford University, described evidence that the gypsum-capped clay floor of a large alkali flat (Danby playa) in the Mojave Desert was similarly lowered more than ten feet in only a few thousand years.

While the activities of winds, streams, landslides, waves and glaciers are all undoubtedly important in removal and transportation of rock fragments, these geologic agents of gradation co-operate so intimately, at various rates and degrees of emphasis in various environments, that it is difficult to rank them in order of relative importance. Where hard rock ledges can be undermined by the crumbling of soft strata, or where natural soft spots or zones of weakness are present in otherwise massive formations, various kinds of overhangs, caves and arches may be developed by any or all of these geologic agents.

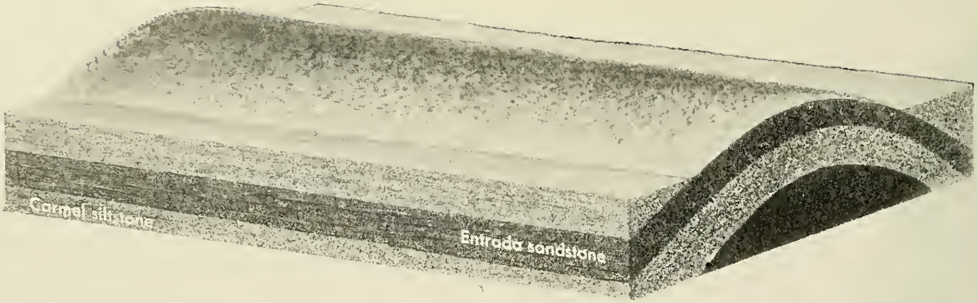
Where the crumbling surfaces are sheltered from moving streams or films of water, and where there is no suitable slope for the dislodged particles of rock to have been rolled away by gravity, it is obvious that the wind, alone, has been responsible for enlargement of hollows and caves in chemically insoluble rocks. Yet, such cavities —definitely attributable to work of the wind—are small



Removed from matrix, wind-carved Cambrian pebbles were found by Professor James Fisher in Bighorn Mountains.



Recently shaped by wind, these pebbles are nonetheless indistinguishable from their ancient Cambrian counterparts.

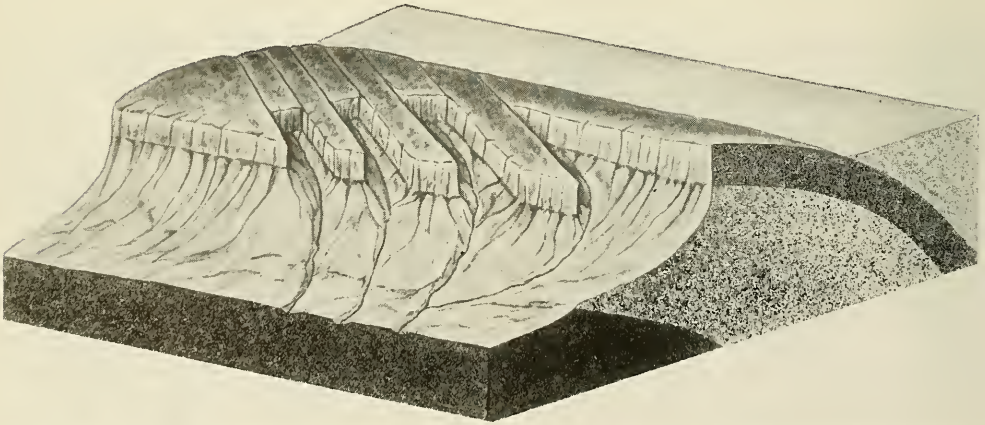


First step in development of landscape at Devil's Garden came as overlying formations of the Salt Valley anticline were stripped down, by process of erosion, to the level of Entrada sandstone (upper dark layer in the block diagram).

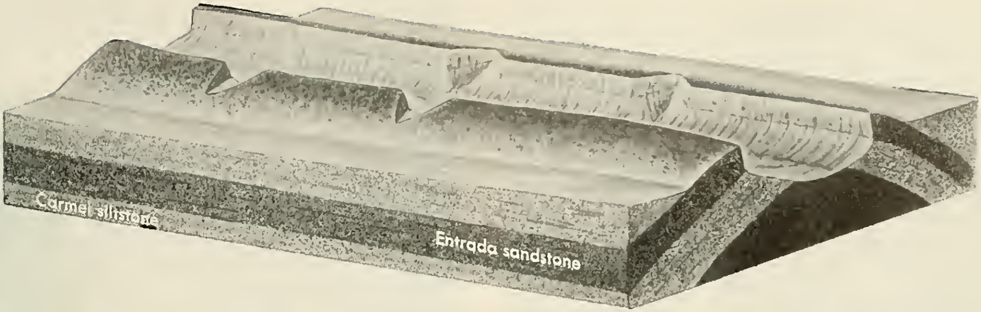
in size and uncommon in occurrence. Usually rainwash and gravity have played a supporting, if not the major, role in the development of overhangs and cavities of all sizes. Of course, the various powers of all these agents of transportation are rendered relatively ineffective until the ubiquitous operations of weathering have weakened the rocks and made material available for removal.

Pedestal rocks, pinnacles and arches may develop in humid regions, but they are most conspicuous in desert regions, where winds rip across the barren landscape. Hence the common misconception that wind abrasion has been the chief process in shaping these bizarre forms. Although this idea has been a matter of considerable controversy among geologists, the final word in the dispute belongs to the late Professor Kirk Bryan of Harvard University. Bryan concluded: "If the upper block of a rock formation is porous . . . and absorbs part or all of the rain that falls on it, the circulation of water *within* the mass of the rock promotes weathering by solution. Sandstone is particularly susceptible to attack by water absorbed from rain. Generally, the water dissolves the cement and, traveling on original lines of easiest passage, emerges at the sides or base of the rock, where it runs out or is evaporated. At or near the point of emergence, the rock crumbles into its original sand grains, which fall away or are carried away by rainwash. The intricacies produced by this process are truly marvelous. In general, an excavation or eating back of the original mass takes place, and the process may be called differential sapping." The same sort of process, extended in time and space, results in the crumbling of cliffs and the stripping of countless plateaus and mesas, as in the distinctive landscapes of the colorful Colorado Plateau.

In the specific case of Arches National Monument (note block diagrams here), it is this differential sapping—and the accompanying processes of waste removal—that have resulted in a magnificent display of geological scenery, through a rare combination of rock types, color, prominent sets of parallel joints to guide erosion, and a



Closer view shows the alternating buttresses and alcoves in the Entrada formation, as springs and seeps, checked by impervious siltstone below, emerge to undermine sandstone ledges. Fracture pattern acts as a guide for this erosion.

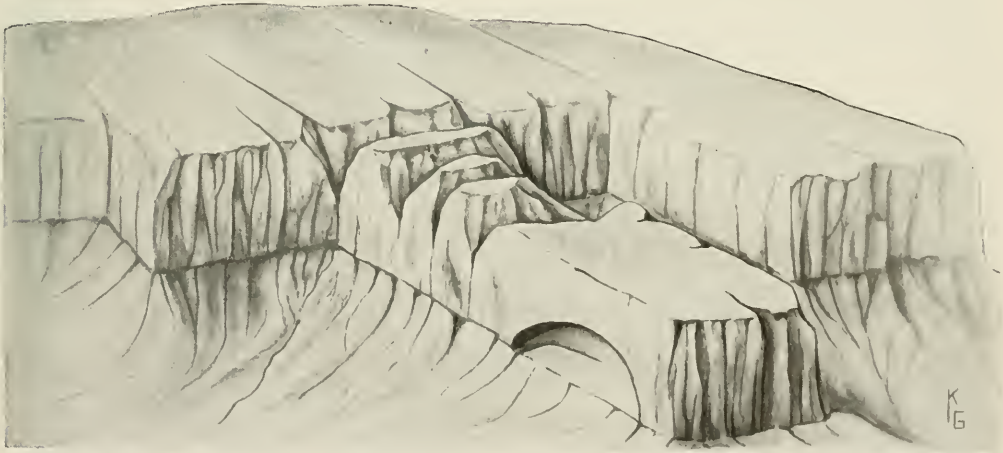


Next step was the uniform breaching of the anticline, by erosional hollowing-out of the weak Carmel siltstone (next layer in diagram), where extensive fractures of overlying sandstone were parallel to the axis of the anticline's fold.

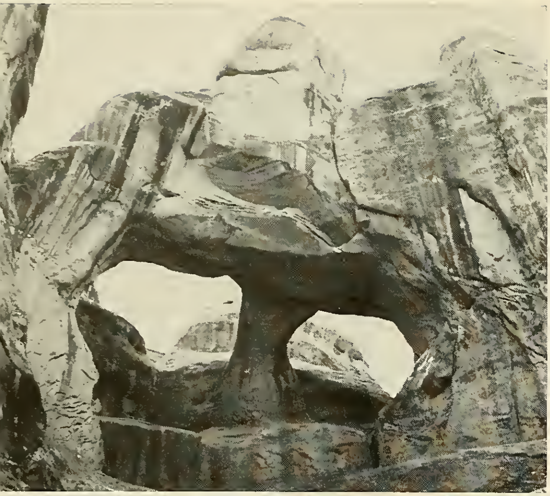
lack of vegetation to hamper erosion. The stage was set for the development of the arches and related features, many millions of years ago, when the rocks of Arches Monument and thousands of feet of overlying strata were slowly buckled upward in the Salt Valley anticline. Long continued erosion stripped away the covering layers, gradually uncovering the massive Entrada sandstone formation in which a prominent fracture pattern had been developed to perfection under the strain of the earlier deformation. As continued erosion breached the vulnerable crest of the Salt Valley anticline, the weak siltstone strata of the Carmel formation were exposed, contributing to extensive sapping at the base of the Entrada sandstone cliffs. Erosional widening of the fractures has permitted sapping to attack the rocks from all sides and to develop an endless variety of weird forms, as irregular zones of weaker rock are etched out.

According to the National Park Service brochure on Arches Monument: "It is in the fins (joint blocks forming vertical slabs) that the arches form. . . . Under the influence of freezing and thawing and the pull of gravity, blocks break away, leaving holes or windows perforating the fins. The pressure at the base of these fins is so great from the overlying weight, and the rock so weak, that great chunks break away and roll down the slopes. Such crumbling and spalling of rock at the base of the fins are similar to the failure of high masonry walls unsupported by buttresses."

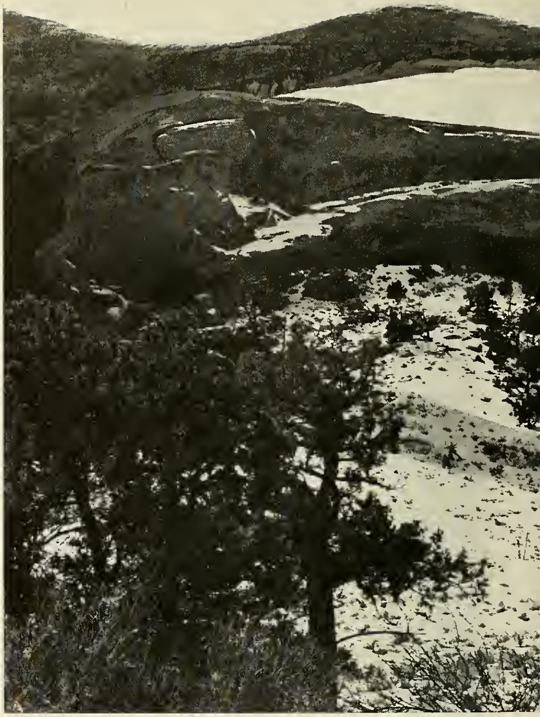
More recently, the idea of failure of massive rocks under compression or release from compression, with spalling toward unconfined surfaces, has been cited as an important aspect of cave and arch formation. Dr. William Bradley, a brilliant young professor of geology at the University of Colorado, explains the process thus: as a sheet of massive rock, once formerly compressed under the burden of overlying strata, is gradually stripped by erosion, the portions of the elastic rock mass near the surface slowly rebound most readily toward free surfaces of canyon walls, giving rise to release fractures,



Final closeup shows vulnerability of isolated buttresses to erosion. Spring-sapped caves, on opposite faces of fin, *center*, may expand and intersect to produce natural arch, or sapping from all sides may combine to produce pinnacle.

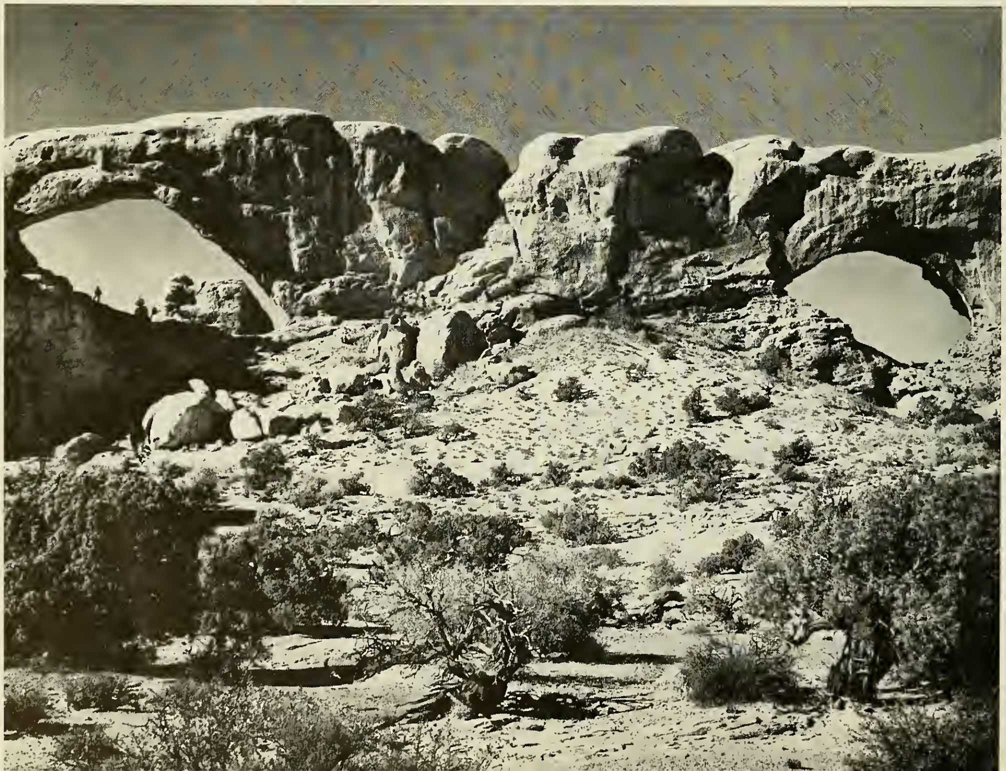


Differential weathering, at work on pair of weak spots in Entrada sandstone, *above*, is responsible for Twin Arch.



Climax of cycle in arch development is epitomized by the sliver-like span of Landscape Arch, *above*. Both buttresses

Sapping from opposite sides of joint block, *below*, caused two wide-spaced perforations in fin: thus, The Spectacles.



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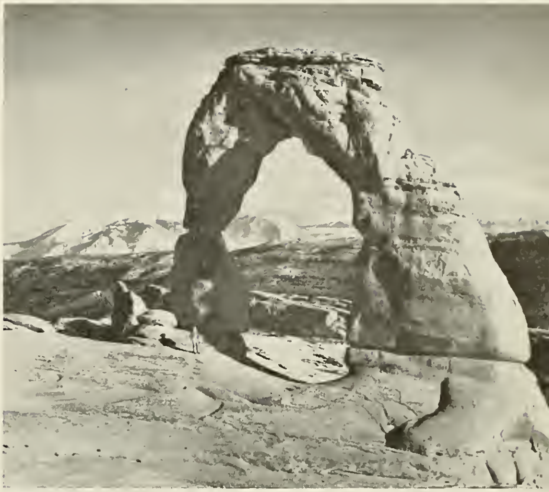
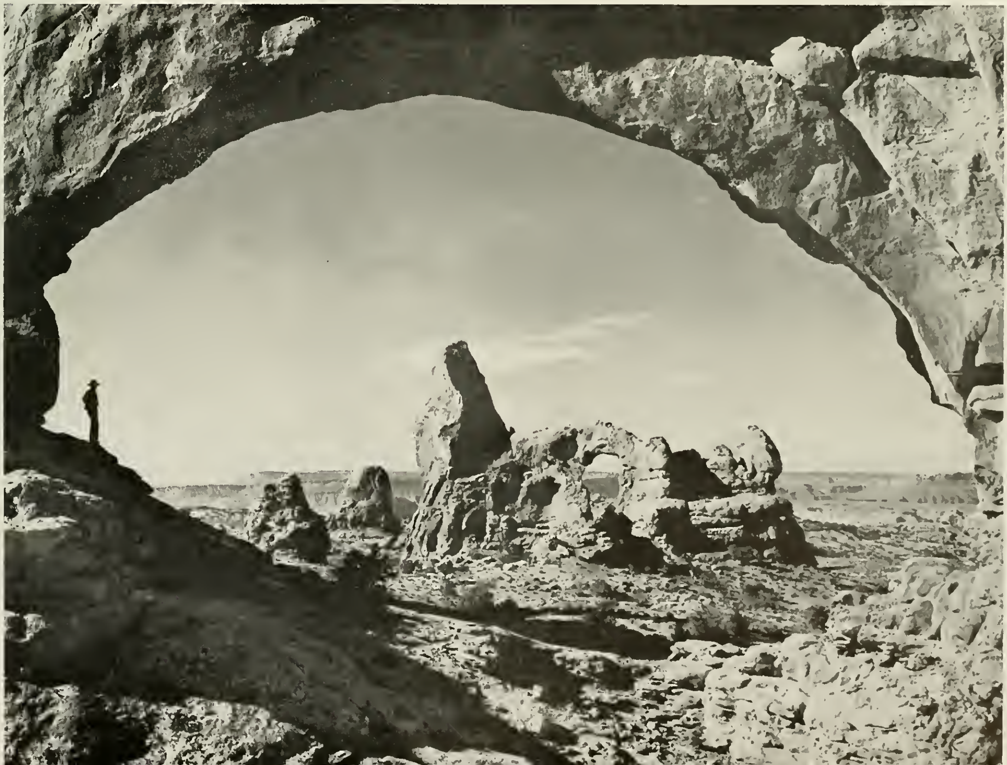


Farther limb of Delicate Arch, *above*, includes bedding of weak siltstone that has contributed to its more rapid decay.

and the arch itself are extensively undermined as a result of steady weathering, crumbling of soft Entrada sandstone.

Cluster of buttes in background, *below*, preserves a single formation, Turret Arch, in array of decapitated buttresses.



Eroded hoodoo, *above*, is the crumbled remnant of a small joint block, known at Arches Monument as Balanced Rock.

which are vertical or very steeply inclined. At greater depth, the tension of release is affected less by the local relief than by the general free surface of the earth; and the successively deeper fractures tend to be more gently inclined. As a result, the release fractures converge toward the lower parts of the canyon walls or cliff faces, giving rise to huge wedges which are thinnest and weakest in their lower parts and crumble or collapse there to initiate cave or arch development. The major crack or joint at the rear of the newly formed cave promotes further weathering and enlargement of the cave.

Consider, in conclusion, additional evidence that casts doubt on wind abrasion as a significant factor in producing arches and similar features. First, leeward and windward surfaces are usually carved and smoothed alike. Second, the necks of pedestal rocks and the surfaces of arches are usually soft and powdery (wind-abraded surfaces are hard and polished). Finally, many arches and other overhangs are found high above the level at which winds should ordinarily carry the gritty particles that are required for abrasion.

The late Dr. H. E. Gregory, Professor of Geology at Yale University, geologist with the U. S. Geological Survey, and a lifetime student of the Colorado Plateaus and their magnificent arches and other land forms, placed the question of wind erosion in its proper perspective.

"In general," Gregory summarized, "it may be said that direct abrasive work of the wind is not a prominent feature, but as an agent that removes the products of decomposition . . . the wind has high value."

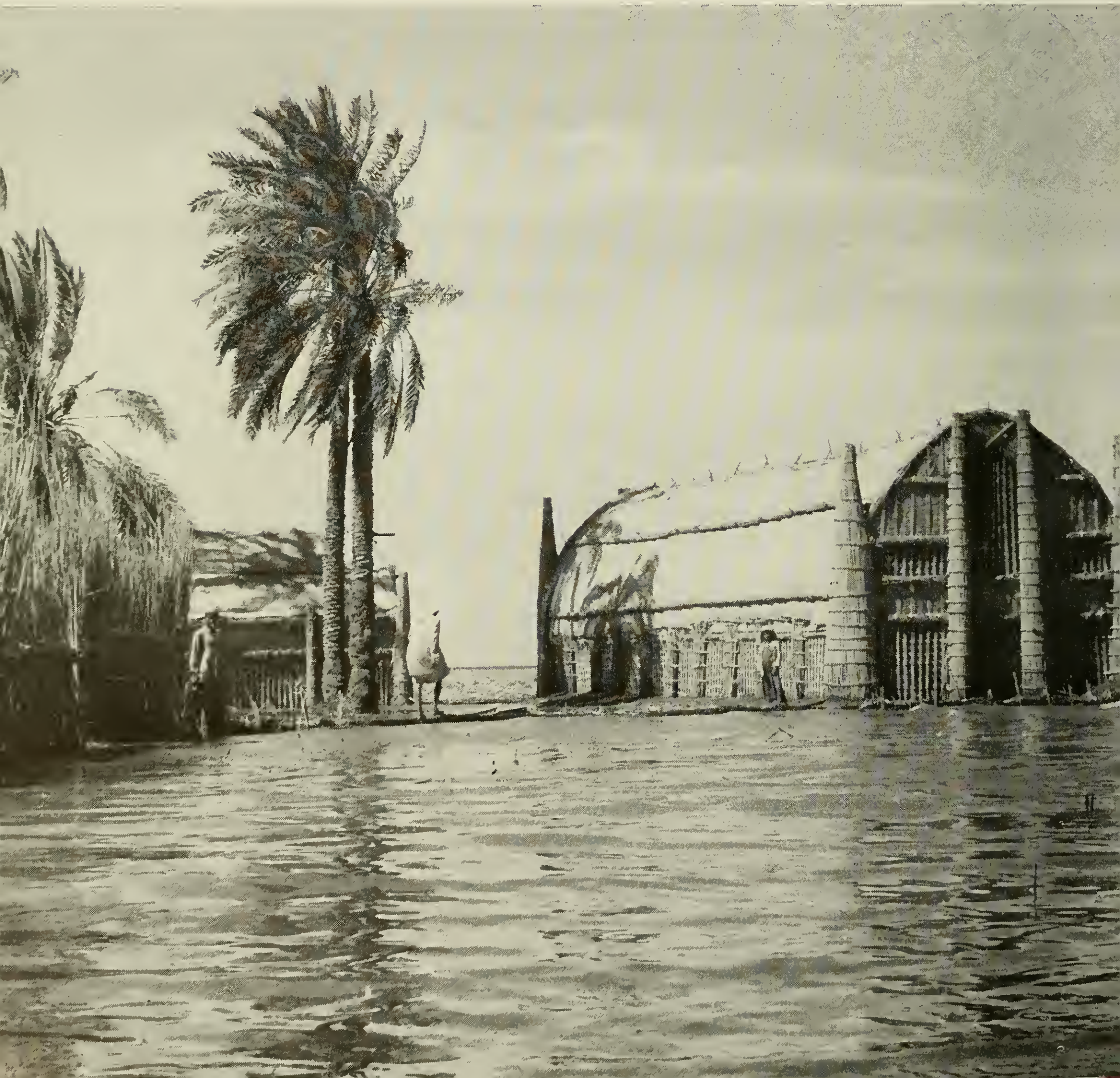
Jumbled pinnacles of Devil's Garden, *above*, show how the erosion has followed the sandstone's closely spaced joints.

Spectacular chute in Fiery Furnace, *right*, is product of slight displacement, faster erosion of the inclined block.

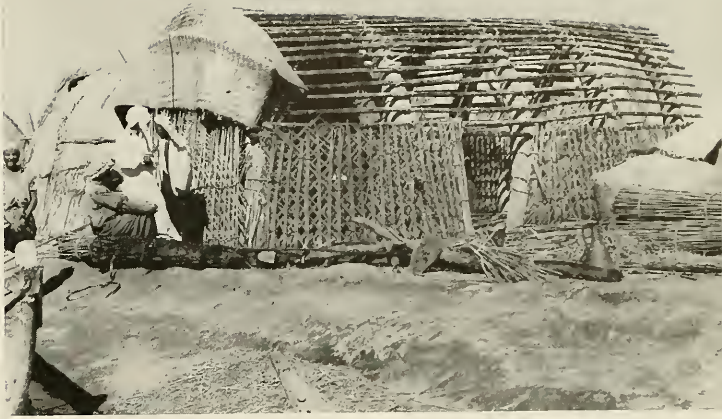
The Ma'dan: Marsh Dwellers of Iraq

By Gavin Maxwell

A little-known group of tribes, living under incredible hardships, depends for existence on their boats, their water buffalo, and reeds



Moving day comes at floodtime for a marsh dweller. Matting is stripped off, heaped on boats, taken to dry ground. To rebuild, the Ma'dan cut new reeds.



Sheik's guesthouse, or *mudhif*, waits out flood in marshland. Made entirely of reeds, a *mudhif* may be about forty yards long. Its door always faces Mecca.

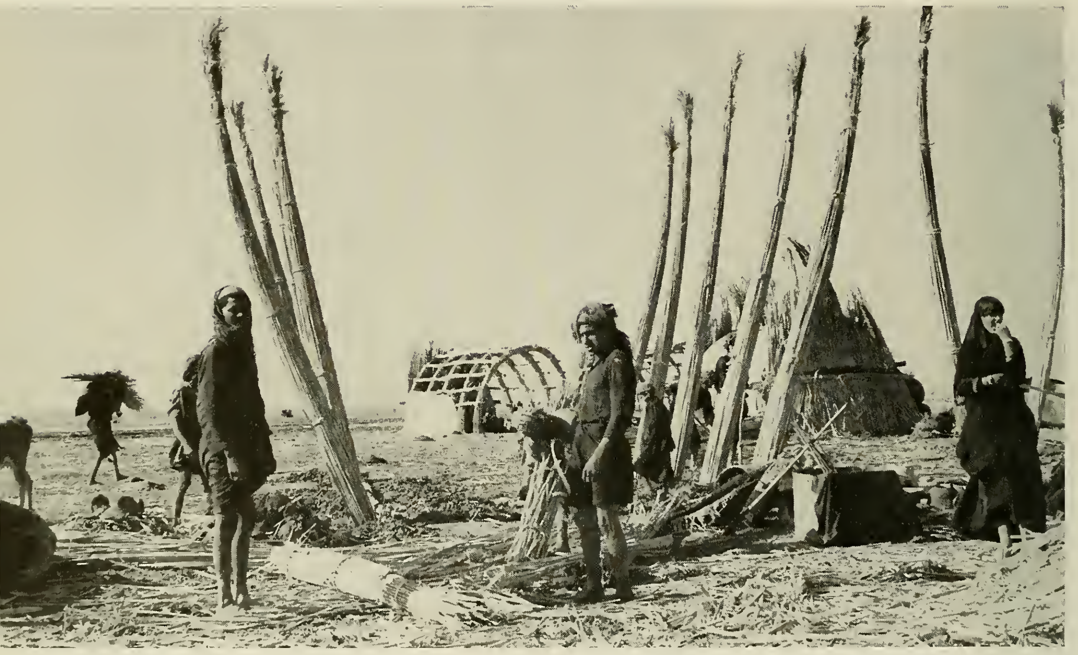
UNTIL A FEW YEARS AGO it was commonly held that, as recently as Biblical times, the Persian Gulf stretched far up the country now known as Iraq, and that the great rivers Tigris and Euphrates flowed separately into the sea (not, as they do now, through the common conduit of the Shatt al Arab). Illustrated Bibles often contained maps showing the recession of the sea at various dates. It was thought that as the sea receded it left behind it a country of marshes, creeks, and lagoons, which were settled in early times by immigrants from the Persian and Turkish highland regions.

Recent research, however, has thrown much doubt upon that accepted theory. It is now believed that these great stretches of marshland—divided into areas of seasonal flooding, semipermanent marsh, and, at the heart of the many distributaries of the two great rivers, a central area of permanent marsh—have been created by subsidence corresponding to upward movement among the mountains farther to the east. Thus, it seems probable that the huge marshes of the Tigris and Euphrates have never been greatly different from what they are today, and the origins of the people who live there, leading a strange life adapted to their unusual surroundings, remain obscure.

The permanent marshes lie low between the courses of the two great rivers, and extend east of the Tigris over the Iranian frontier. They are one of the almost unexplored territories near to civilization, for they are within a day's journey of great oil fields. Transport difficulties, the lack of solid ground on which to pitch a camp, and the primitive living conditions of the marsh Arabs have discouraged most travelers from penetrating beyond the fringes of the permanent marsh. Whereas both the areas of seasonal flooding and the great rivers themselves have been visited by travelers, as well as by soldiers in wars of European origin, the heart of the swamps remained little known and imperfectly explored until Major Wilfred Thesiger began to visit it some six years ago. Since then, until the time of the Iraqi revolution, he has spent a number of months of each year in the marshlands, and among its peoples. Thesiger has done much for them, tirelessly doctoring with modern drugs the many ailments to which they are subject, and to be his companion was a passport to their good will. In the winter of 1955-56, I accepted an invitation to accompany him into the marshes the next spring.

THIS is a tribal area, inhabited by some half-dozen tribes whose frontiers extend arbitrarily outside the marshes. Some of them claim to be of Arab descent, and contain a liberal sprinkling of sayids, or descendants of the Prophet, while others deny Arab blood and say that they lived there long before the Arab invasion in the Dark Ages. In the days before World War I, when the whole of Iraq was part of the Ottoman Empire, the Turks encouraged intertribal warfare, hoping thus to keep the people in a state too weak and divided for combined revolt against their overlords. By 1956, although there was from time to time a little local scrapping, fights rarely reached a stage at which the intervention of government troops became necessary.

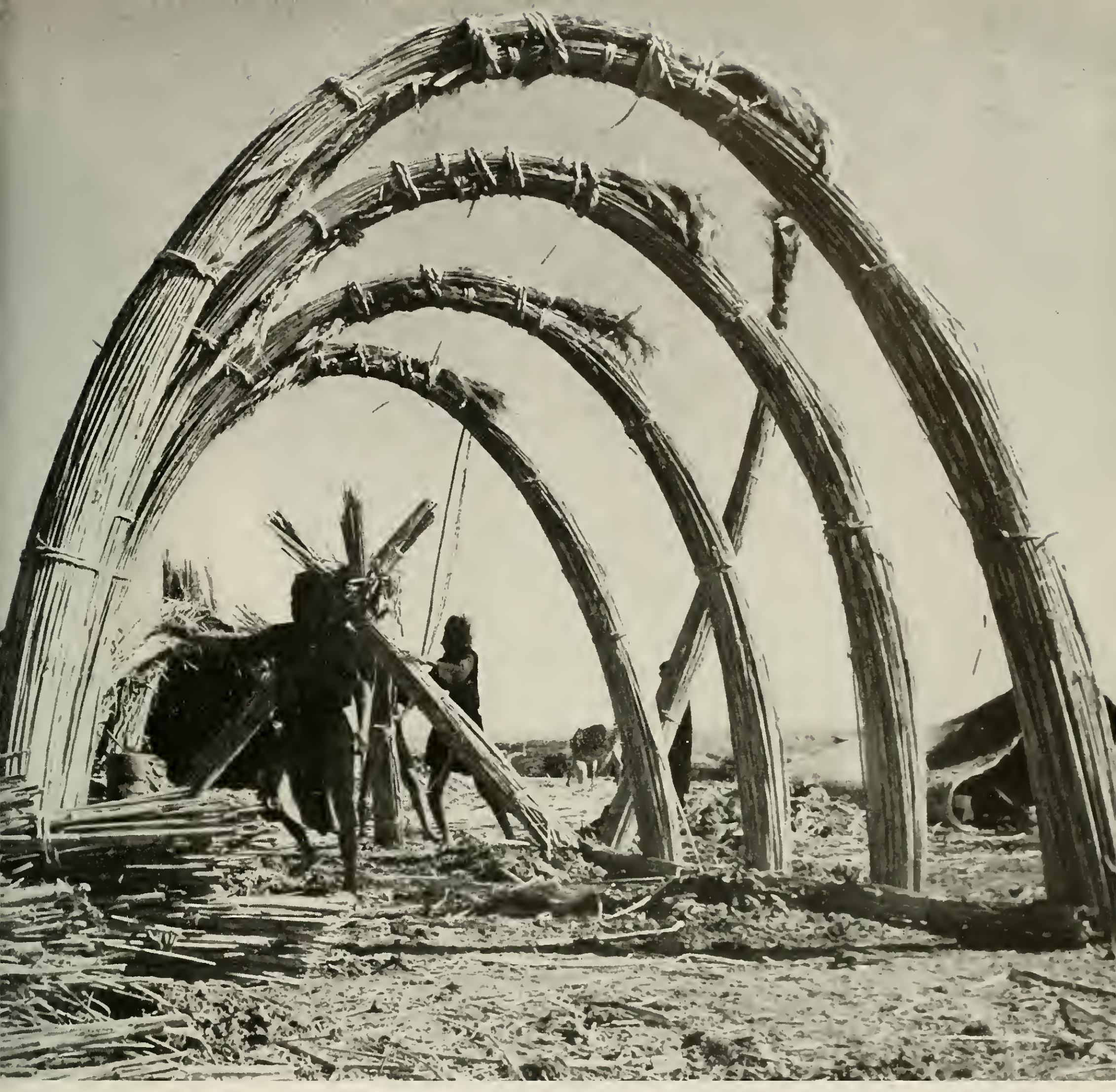
WHILE the land of Iraq belonged nominally to the State, sheiks held land under the government in a type of perpetual fief, and were responsible to the Crown for the good order and discipline of the territory they occupied—not always, it must be admitted, to the benefit of their people. These "landowning" sheiks did not live in the marshes themselves, but usually in stone fortresses on the dry banks of the rivers. They kept agents in the various marsh villages, whose duty it was to levy taxes and maintain order. Many of these sheiks were related to each other by marriage, and occasionally family disputes would lead to one sheik going to war against another. Their men were usually well-equipped with rifles, but had no heavier weapons than light machine guns.



FIRST STEP in house construction is bundling reeds into tapered columns, which are set into parallel holes and are then angled out at about 70°. Framework is next covered by overlapping mats, made of reeds, as shown in background.

The earliest settlers in the marshes, from wherever they may have come, were faced with the problem of wresting a livelihood from a country in which there was little solid ground, except for an occasional small tumulus island of mud, and which contained few materials either for shelter or for food. Probably they were, as they are now, dependent for certain necessities upon the cultivators who live outside the perimeter of the true marsh (which can grow no crop of any kind), exchanging their own products, notably reed matting, for rice and other foodstuffs. For building material they had nothing to use but the giant reed *Phragmites communis*, growing twenty-five feet high, which is the chief vegetation of a large part of the area. This reed became the mainstay of the people, and remains so, even to this day.

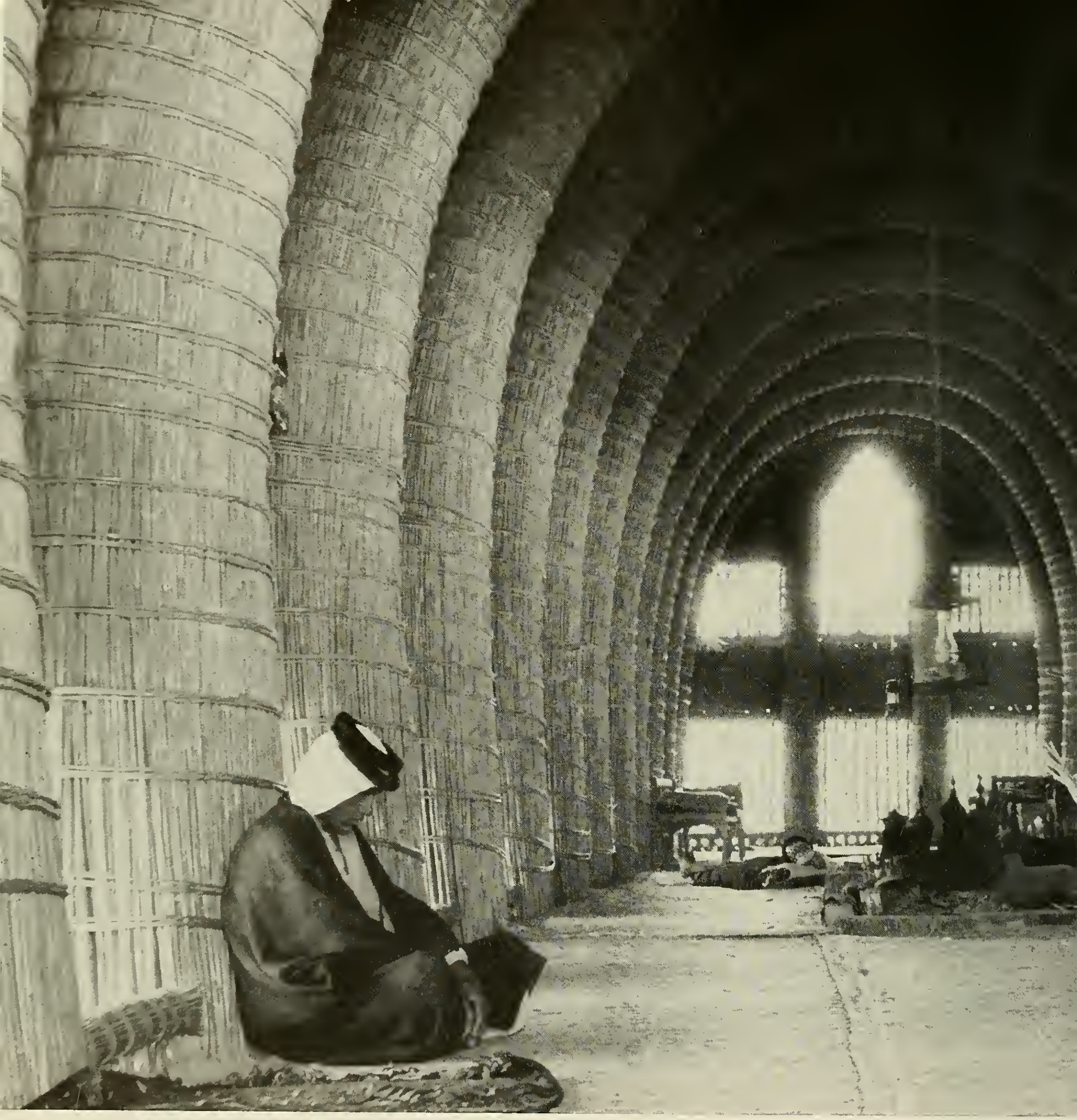
THE marshmen like to build their houses in the more open water, away from the denser reed beds, so as to avoid the worst of the mosquitoes in summer. In water, which is some two or three feet deep, they stake out the perimeter of the proposed house with short stiff bundles of reed and then fill in the enclosed area with vegetation, until a little island is formed just above the surface of the water. Then bundles of the full-length reeds are cut, bound together, and stuck in the "ground" to a depth of some three feet; they are bent over and their tops tied together to form a succession of arches, which then become the main bones, so to speak, of a marshman's house (see illustrations). After the horizontal bundles of reeds have been added, there is an integrated structure not unlike the skeleton of any Quonset hut, which is then covered with reed matting. It has been suggested that such reed arches were in all likelihood the predecessors of all arch formation in architecture, for the making of an arch is clearly more convenient in such a plastic material than in stone or brick. The structures vary greatly in their degree of pretension and ornamentation; the usual marshman's house, whether built on an island or in the water, is small and generally rather untidy, but the perfection to which this tradition of reed architec-



Ends of columns are bent together and tied with sedge leaves, *above*. Tripod is "stepladder," made of bundles of marsh reed, and is strong enough to support a man, *below*. Three men can construct a marsh house in about two hours.

ture can be brought is illustrated by the guesthouses or *mudhifs* of the sheiks who live on the perimeter.

THESE are of most intricate construction and considerable size, often ornamented with lattice windows at the ends, and they are solid structures that may take hundreds of men several weeks to build. By contrast, the simple marshman's house can be put up by members of the family in two or three hours.



While building material was thus readily available to an inventive mind, there was originally no form of livestock in Mesopotamia that was suited to this aquatic life, and it is not surprising to find that a people who had already displayed so much ingenuity were quick to set this right by the introduction of the water buffalo, now a key element in the marshman's economic system.

These animals are so essential a part of the marshman's life that the routine of the family may be said to revolve about them. They provide both milk and cheese, and, most important of all, they provide the only safe fuel available in the marshes—their dung. Reeds are an unsuitable and dangerous fuel to burn in a low reed house and a fire of reeds requires constant tending. Thus, buffalo dung is the staple fuel in every household. It is collected—by children or women, who are always responsible for such "unclean" tasks—made into platelike patties, dried, and finally stacked into beehive-shaped structures of great intricacy. Buffalo dung is also used as cement, a function scarcely less important than its role as fuel: grain stores of reed matting are sealed and waterproofed with buffalo

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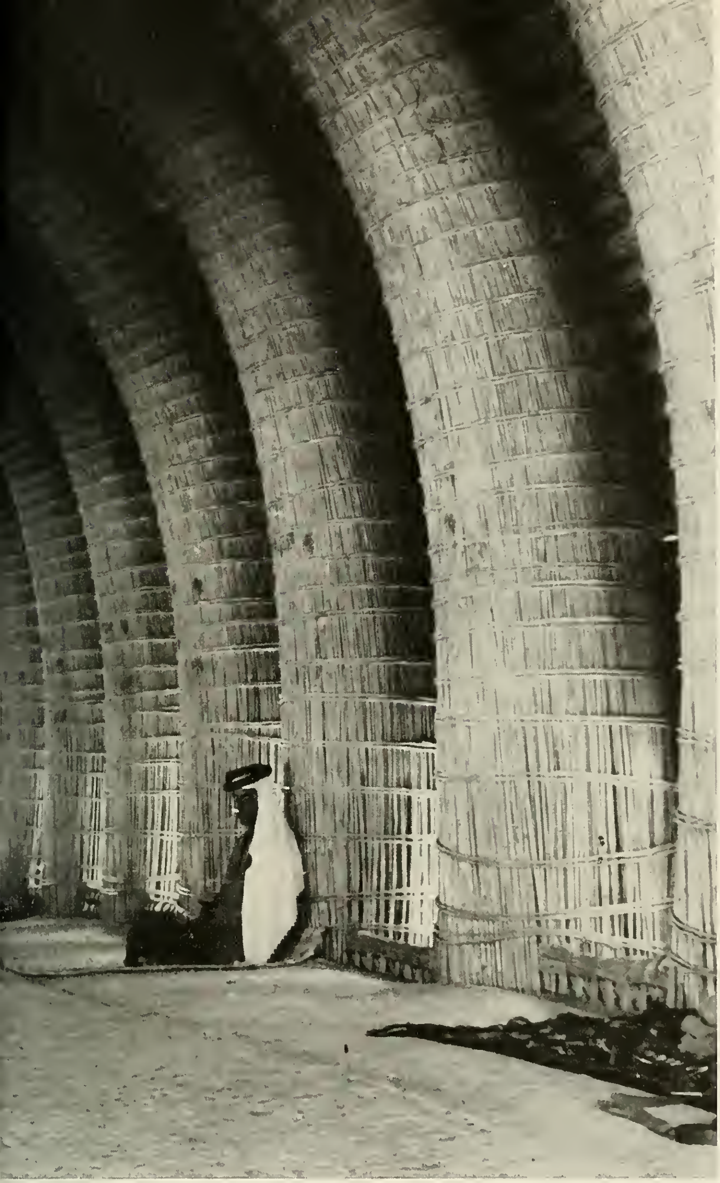


Impressive interior of *mudhif* shows details of arch construction—a style so old that it is possible many later architectural forms derived from it.

dung, which sets as hard as a rock.

Because of their indispensability, the buffaloes have become to the marshmen almost a unit of currency, and each beast is worth some seventy-five dollars. A man purchases his bride for three buffaloes or an equivalent cash payment. The settled people of the marshes may own from two to a half-dozen buffaloes per family, but at the fringes of the marshlands nomadic peoples are to be found, who herd great numbers of the buffaloes, moving as the grazing may dictate. There, a single family may own a hundred or more animals.

Besides his buffaloes, the settled marshman usually keeps a few chickens and one or more savage dogs who guard his house from the ever-present menace of theft. More occasionally, he may own one or two sheep and dun-colored cows. These latter remain for all their lives upon the buffalo platform that projects from every house, and when the buffaloes leave the platform at dawn, to forage in the reed beds, the cattle must stay, dependent upon the green shoots which their owners cut for them.

The ingenuity displayed in the exploitation of the natural reed growth, together with the introduction of water-loving livestock, suggests that the early settlers would also have been quick to exploit the very numerous fish inhabiting the marsh waters. Thus, it remains an unanswered puzzle that the true marshmen look upon fishing with nets as something caste-losing and almost unclean. Although a net-fishing community—called the Berbera—lives in their midst and makes larger sums of money than would ever come a marshman's way, the marshman regards the Berbera as inferior people, with whom, for example, he would not dream of intermarrying.

The marshman confines himself to the grotesquely inefficient method of fishing with a five-pointed spear. He will wade about for hours in the reeds, thrusting this clumsy but formidable weapon at random among the reed roots. At the end of it all he will, by luck rather than by skill, bring home three or four fish.

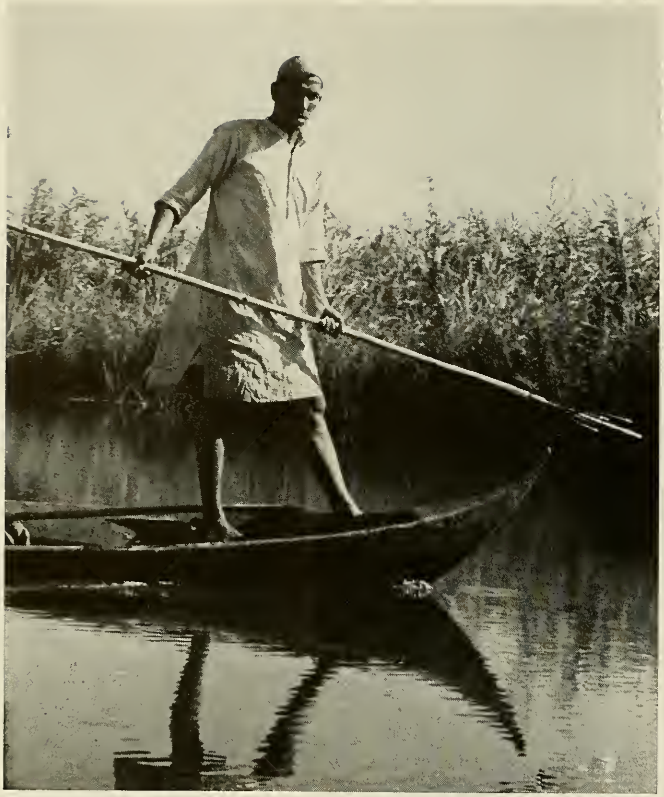
Thus, the marshmen never "export" fish in exchange for the goods they require, and their exportable produce is limited to reed matting. The matting is collected by trading boats that move from village to village, and is thereafter often taken to Basra and sent not only to other parts of Iraq but also to countries overseas.

Besides grain in one form or another (the staple food is rice), there is one other commodity which the marshmen are unable to produce themselves. As there is no solid land in their territory—or at best a few mud islands barely large enough for a few families to build their houses upon—the people are dependent upon canoes or boats of one form or another for all movement. These canoes

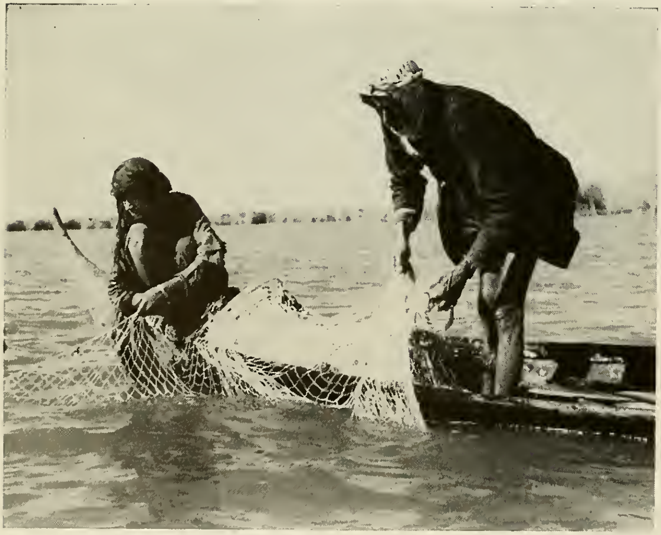
—varying in type from broad-beamed transport boats to the graceful high-prowed *taradas*, which were the tribal war canoes—must be built outside the marshes, upon the great rivers or their distributaries, and must be bought by the marshmen in return for their staple product—reed matting.

A child learns to paddle a canoe as soon as he or she can walk. One may see little children who are still unsteady on their feet practicing paddling a small raft of reeds in preparation for the great skill—characteristic of all the adults—in the handling of the marshmen's unstable craft.

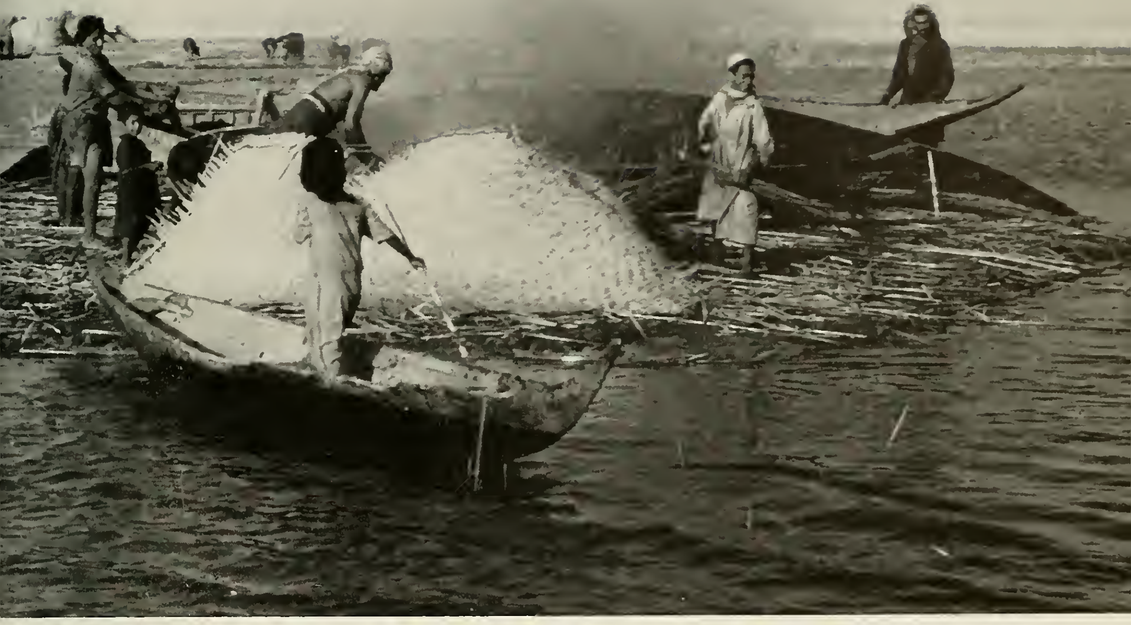
THE commonest type of weapon in the marshes is the muzzle-loading shotgun. These are made locally, and look it; the barrel may be any old piece of metal tubing, and several that I saw had quite plainly been constructed from old iron bedsteads, of which some enterprising peddler had perhaps carried a load to one of the river towns surrounding the marshes. The crude forestock is attached to the barrel by encircling strips of raw aluminum or brass, and sometimes the owner decorates his weapon by nailing a coin or two on to the stock. The ammunition for these perilous-looking contrivances can be bought at most of the larger villages outside the permanent marsh. The



POISED PRECARIOUSLY in a canoe prow, this Ma'di prepares to spear for fish. Because spear method is so inefficient, Ma'dan do not get enough fish to sell.



FISH NETS, tabooed by the Ma'dan, are employed by the low-caste Berbera—strange, seminomadic people with whom Ma'dan will not eat or intermarry.



Lifeline for every Ma'di is his canoe. In it he fishes, hunts, gathers reeds, visits the outside world. Here, bottom of boat is waterproofed with hot tar.

Mats, *left*, woven by Ma'dan, are sold widely in Iraq and beyond its frontiers.

Keffia, a cross-wrapped headdress, is worn by Ma'di, working at his loom.

GAVIN MAXWELL grew up in Scotland, studied at Oxford before World War II, and now lives alternately in Skye and London. His interests: "natural history, psychology and the arts."

charge is black powder. Flat sheets of lead pellets, joined together—from which one may break off as many or as few as one likes—provide the load. The pellets are not round but neither, for that matter, are many of the gun barrels. When the owner is unable to afford the lead, he will load it with what scraps he can find, although metal of any kind is scarce.

ALTHOUGH the impact of the West has yet to penetrate the permanent marshes, dependence upon the people who live on the dry land outside has resulted in the introduction of a number of Western commodities during the past few years. Thus the peddling boats that tour the marsh villages have now begun to sell such innovations as safety pins, plastic belts and bandoleers, and bales of cheap, brightly patterned cloth from India and Japan. These peddling boats, too, supply the village shops, which are indistinguishable from any other reed house but for the fact that they fly a small white flag. In some of them there are a surprising variety of goods, and, in addition to the plastic belts and cloth, they stock rice, sugar, and cigarettes. Tobacco is extraordinarily cheap in all Iraq, and twenty well-packed cigarettes cost no more than five cents. Almost all marsh Arabs smoke, many of them starting when they are five years old. and they economize still further by buying their tobacco loose and rolling their own cigarettes, thereby cutting the expenditure practically in half.

VARIOUS clothing can be bought at these shops, but the marshmen's requirements in this direction are few. The basic garment is the *dishdasha*, a single shirt reaching from throat to ankle. When it rains, the marshman does not put on more—he takes off what he has, to keep it dry. Of recent years many men, particularly of the seasonal marshes, have taken to wearing over this garment a European-style jacket (these are imported into Iraq in bulk from America), but they never wear shoes or any form of underclothing. On his head, the marshman wears a headcloth and a head rope to keep it in position — called respectively *keffia* and *agal*—and sometimes, especially among children who have not yet adopted adult dress, a woollen skullcap of bright colors. Men shave their heads; women plait their hair into an elaboration of short pony-tails.

The marshmen are riddled with disease. Dysentery is endemic: yaws afflict a large part of the population; ringworm may be expected among the greater number of children; hookworm spreads rapidly and bilharzia is inescapable for those who spend so much of their time naked in the water. This last, perhaps, may be described as the disease par excellence of the marshmen, for no cure can prevent immediate reinfection.

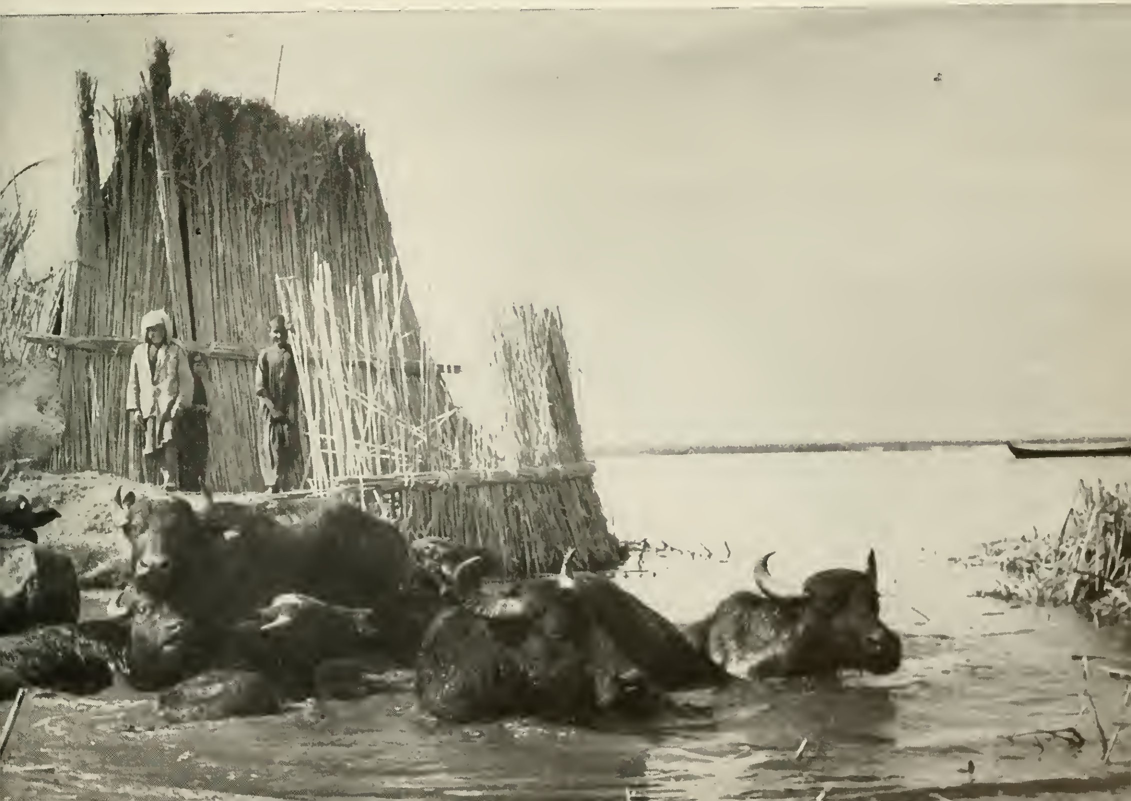
The marsh Arabs are a primitive people, and in the main, despite their living conditions, are a happy and contented one. So far, they have little knowledge that the culture of the West brings with it more than a few amusing new toys. They are not jealous of the sheiks' Cadillacs or of what they know of civilization, simply because these things seem as yet to bear no relation to them. Their interest in new objects is confined to the things that they consider useful to their own way of life. Our guns, field glasses and medicine chests, for example, were jealously admired, but talk of automobiles would leave them cold because clearly one could not use an automobile in the marshes.

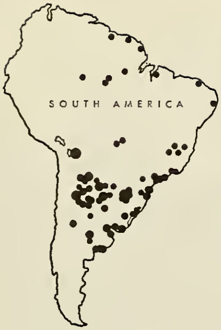
AT present, the marshmen are leading much the same life as their ancestors did some three thousand years ago, but their dissolution under the ever-increasing proximity of Western culture must now be a foregone conclusion. There is talk of draining the marshes—and oil is suspected below them—but such a program would in all probability take so long that the culture of the marsh people will disappear under the blandishments of civilization long before the marshes themselves are no more. When it does so, it is to be hoped that this very likable people will find the benefits of this century, into which they will emerge like Rip Van Winkle, rather than the problems that it has brought to us who have grown up in it. To me it was a privilege to pay this visit to them in their remote and watery Eden before they had eaten of the apple.

MARKET VILLAGE, *above*, is a scene of gossip and of trade, where safety pins,

plastic belts, and Western clothes are exchanged for famed Ma'dan reed mats.

WATER BUFFALO, *below*, are Ma'dan's most prized possession. Dung is used for fuel and caulking, its hide makes leather, and its milk is a diet staple.





INVADER OF THE

Helped by a genetic mutation, the population of the fire ant has "exploded," and now infests a wide area

By Edward O. Wilson

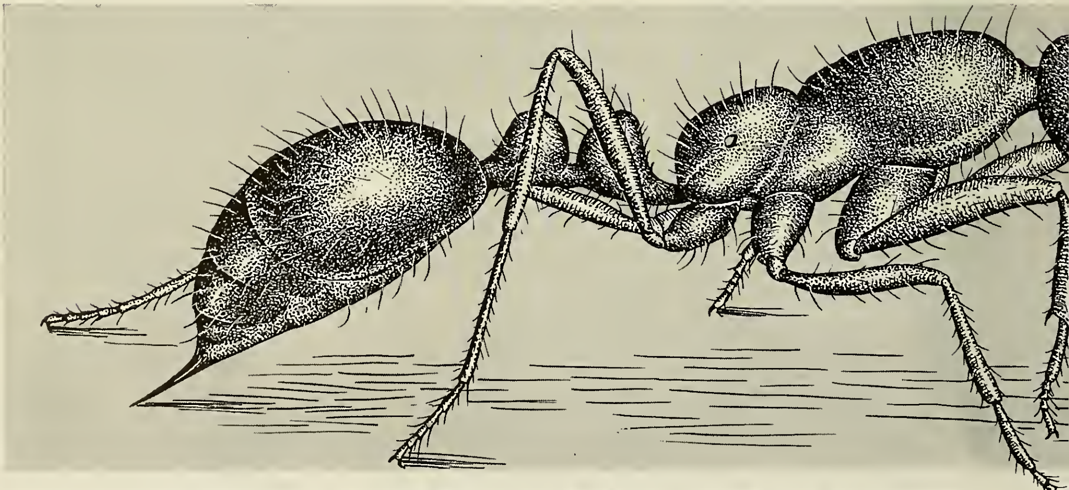
FIFTY YEARS AGO, the chief problem besetting southern agriculture was the presence of the boll weevil, an insect which was then in the process of moving eastward from Texas. Today, equal anxiety is being caused by the imported fire ant, which is spreading in all directions from its point of introduction at Mobile, Alabama. Fire ants receive their common name from the mildly burning sensation caused by their sting. Actually, the sting of the worker ant is much less severe than that of a bee or wasp, but this is more than made up for by the size and ferocity of the colonies—the slightest disturbance of a nest brings out hundreds or even thousands of workers, which attack any moving object within reach. Most persons are not seriously hurt by fire ant stings, but a few are especially sensitive. At least two children are reported to have died from large doses of the venom after an attack.

Aside from causing considerable nuisance, the imported fire ant species has developed into a remarkable, versatile and destructive agricultural pest; for as the populations become denser and the nests more crowded, many colonies enlarge their diet—which normally consists mostly of small insects—to include the seedlings of plants. In Alabama and Mississippi, sections of fields of newly sprouted corn, beans, and other principal crops have been cut down by the marauding worker ants: one picks up crumpled plants only to find their stems and roots riddled by feeding ants. It is a rare thing for any ant species to feed directly on plant tissues in this way.

The fire ants are also avid attendants of plant lice and scale insects, which they solicit for the secretion known as honeydew, and they undoubtedly contribute to some crop damage in this indirect fashion. Their large nests, sometimes occurring as many as fifty to an acre, slow farm machinery and hamper sowing and harvesting operations. Farm workers frequently refuse to work in infested fields for fear of being stung.

But of all the damage fire ants are reputed to do perhaps the most spectacular is the destruction of barnyard animals. Newly hatched fowl are particularly susceptible. Whole broods of chickens and turkeys have been said to be destroyed by the ants within a few hours, when left unguarded. There have even been reports of newly born pigs and calves being killed.

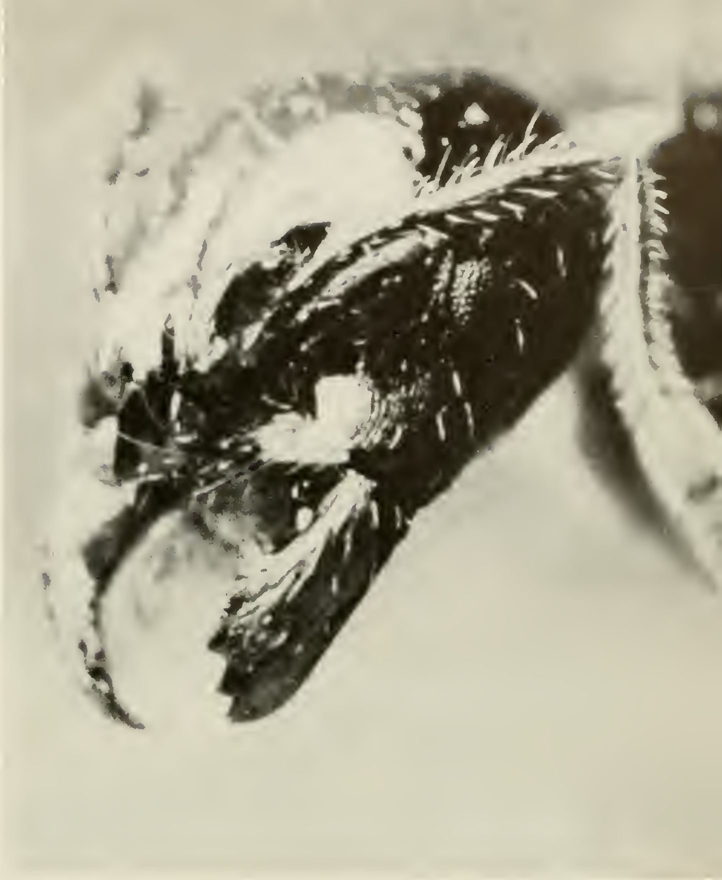
THE size of fire ant colonies is surprisingly large. No accurate counts have ever been made of the population of a single nest, but one estimate I made using statistical meth-



WORKER'S STING, *above*, plays a crucial role in the ants' foraging. When worker finds food that proves too heavy for it to carry alone, it goes back to the nest dragging the tip of its sting along the ground. This emits minute amounts of

SOUTH

Dr. Wilson began to observe the fire ant while studying at the University of Alabama. He then went to Harvard, where he won a junior fellowship and has now become associate professor.

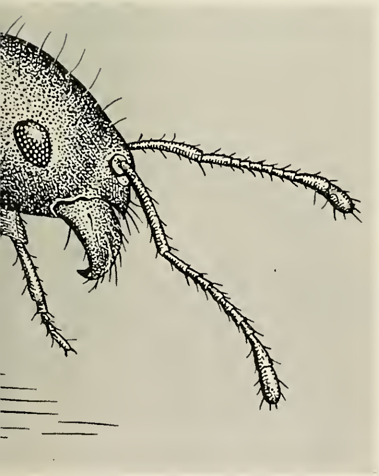


Fierce mandibles show why fire ant is such a voracious predator, eating not only plants and crops, but even certain small animals, like newly hatched fowl.

ods yielded the figure of approximately 250,000 workers. If this estimate is correct—and I believe that, in fact, it is on the conservative side—then it is probably true that the most heavily infested farm land can support as many as 10,000,000 adult worker ants per acre! It is not hard to see why these ants have acquired such omnivorous feeding habits.

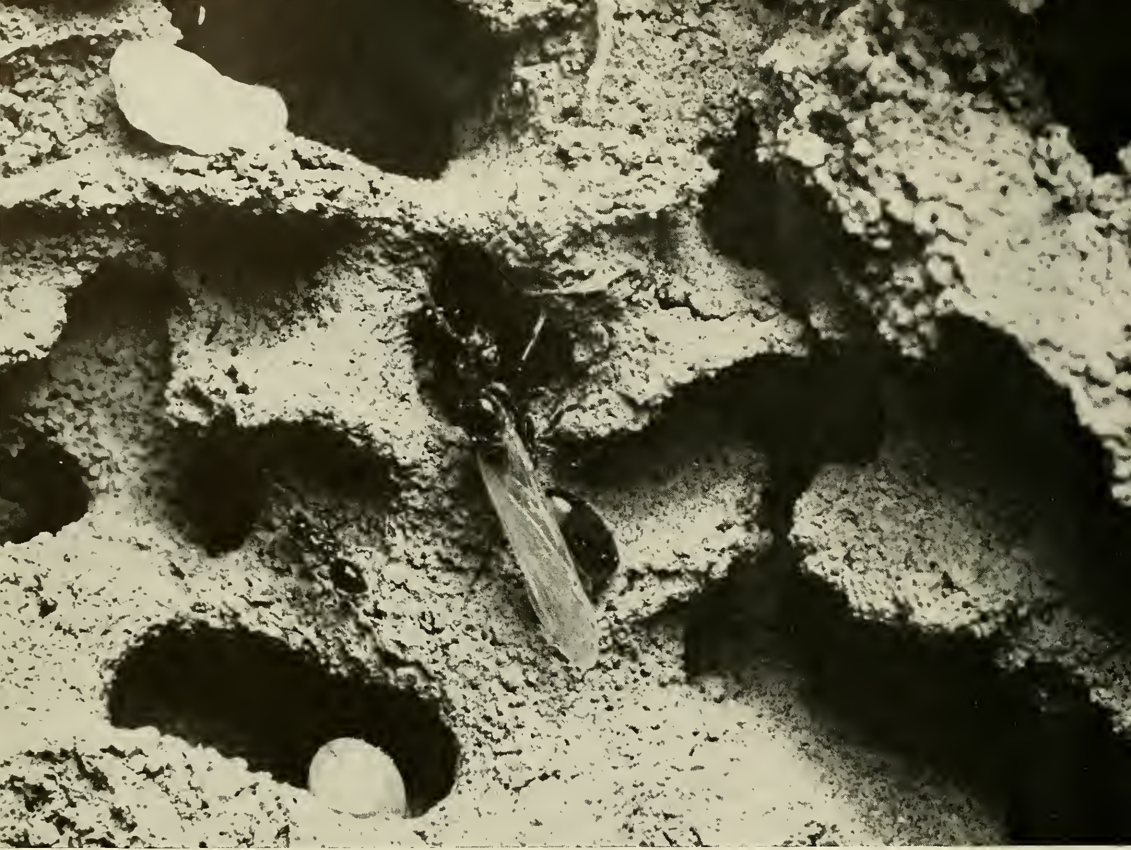
Externally, their nests are marked by a mound of excavated soil, which is usually about three feet in diameter and varies between several inches and one foot in height. Beneath the surface of the mound, the earth is honeycombed for a depth of as much as five feet. Innumerable galleries and chambers are filled with ants and their soft, white brood. Yet, despite the great size of the colonies, there appears to be only one mother queen in each nest.

In order to determine what kind of control was exercised by the colony to limit the number of queens. I once performed a laboratory experiment in which several queens were mixed with a group of workers that had gone without queens for a while. Because fire ants from different colonies are highly antagonistic to each other and ordinarily fight to the death when confined together, it was necessary to chill both the queens and workers in a refrigerator before mixing them. When they recovered, they accepted one another and went about their normal functions in apparent harmony. But after several days, the workers began executing queens systematically, until only a single one was left, thus restoring the normal balance.



scented substance, forming a trail that other workers smell and follow to food.

The control of queens is just one aspect of the tightly knit social organization that characterizes fire ants and undoubtedly contributes to their success. Another, most interesting kind of behavior can be seen when the ants go foraging. The workers patrol singly, during both day and night, with the result that a substantial area around the nest is kept under constant surveillance. When a worker finds food that proves too heavy for it to carry alone, such as a large insect, it leaves the food source and runs directly homeward, dragging the tip of its sting along the ground and emitting through the sting an odor trail, which consists of a substance originating in one of the venom glands in the rear part of the ant's body. Only microscopic amounts of this odoriferous substance are released at a time, so that the trail, even when examined under considerable magnification, is invisible to the human eye. But the trail is very obvious to the olfactory sense of worker ants.

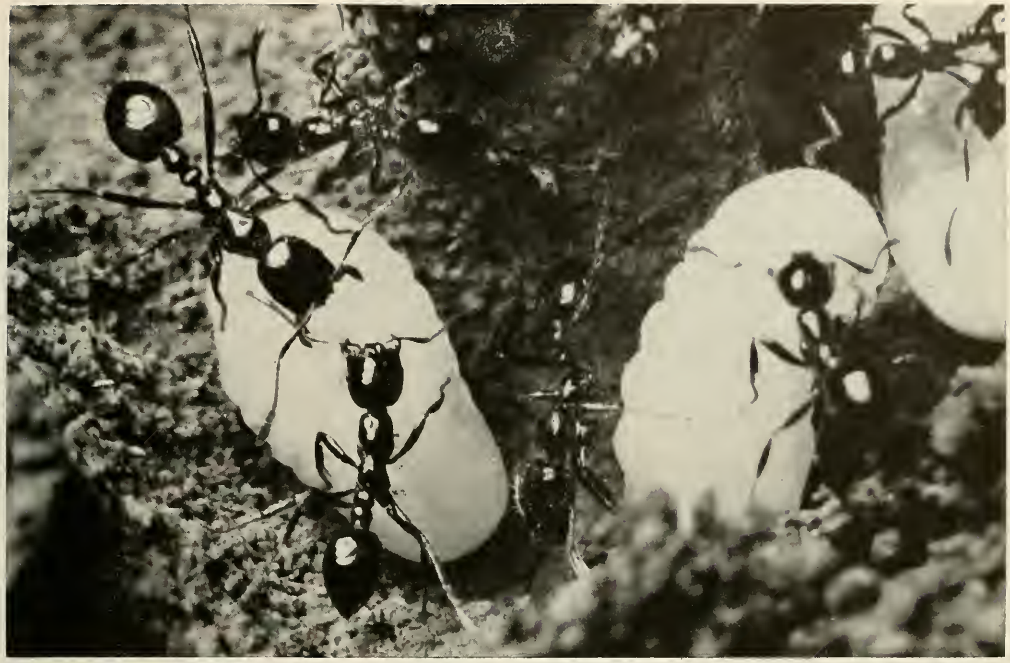


YOUNG QUEEN is seen with larval ants and worker in nest's galleries. Wings will be lost after the mating flight. Despite colonies' great size—there are perhaps 250,000 workers in a single nest—only one mother queen is found to a colony.

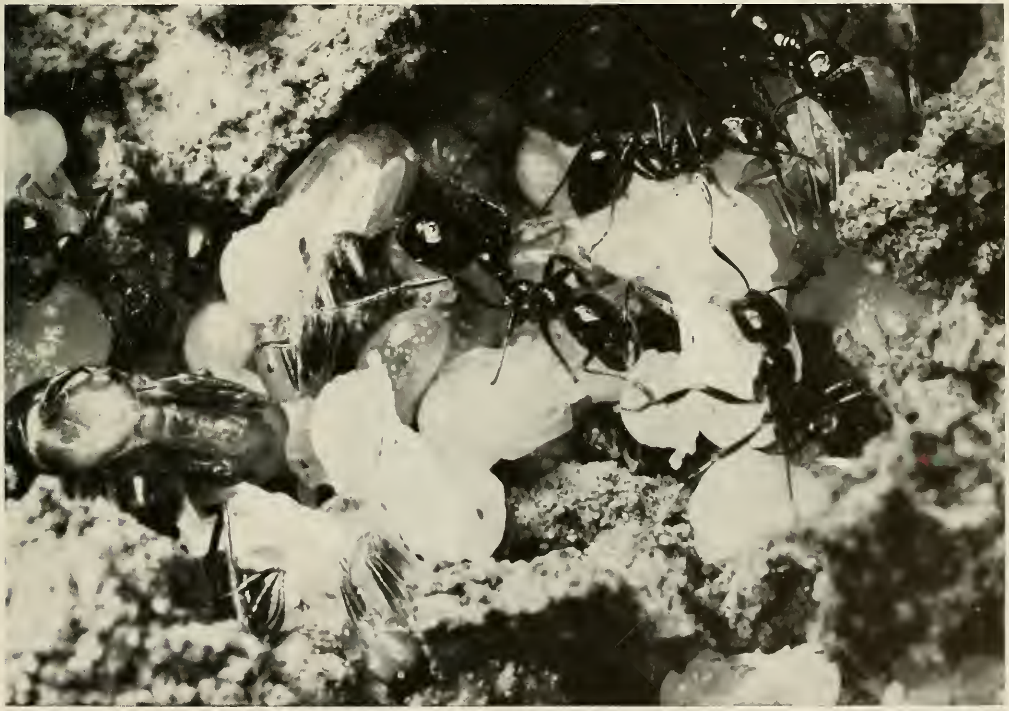
for when the foraging worker reaches home, other workers meeting it immediately begin running out along the trail, and, providing the food source is not more than a yard or two from the nest, they soon find it. Workers subsequently arriving at the scene perform looping movements of their own and also carve off bits of the food to carry back into the nest. As a result of this cumulative activity, the number of workers venturing out to the food source now mounts exponentially, until in a few minutes the spot is swarming with ants. Clearly, the chief advantage of this pattern of behavior is that a relatively small number of foraging workers in the field can, on short notice, bring out the right number of helpers to cope with prey or large food particles.

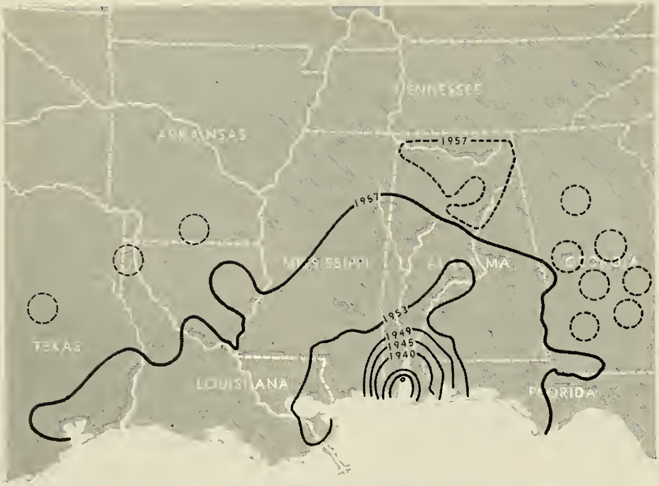
The imported fire ants spread themselves in two fashions. The largest jumps are made by colonies unwittingly carried by man in the soil of nursery stock. From these secondary foci, new populations spread out rapidly. A slower, more natural dispersal is achieved by the nuptial flights of the winged queens and males. At various times of the year, but especially during the summer, swarms of these winged "sexual" forms emerge from the nests and fly high into the air, where they mate. The fertilized queen then drops to the ground and follows a sequence of nest-founding behavior of the sort typical for most ant species. First shedding her wings, she then digs a short vertical gallery in the soil, settles herself in the bottom, and finally (within a few days) lays approximately a hundred eggs. Development of the eggs and of subsequent larval and pupal stages takes place rapidly. Within five weeks, the young adult workers have emerged and begun foraging for food above ground. The growth of the young colony that follows is also astonishingly rapid. Within a year, it contains thousands of workers and has begun to produce winged queens and males, thus completing the social life cycle of the species.

IMPORTED fire ants were first discovered in the U.S. by H. P. Löding, a distinguished amateur entomologist from Alabama. He made his discovery in the port city of Mobile shortly after the First World War. It is typical of introduced pests that at first the ants seemed relatively harmless—indeed, they were limited to a precarious "beachhead" within the city itself; and during the 1920's, Löding observed how another species of ant, the famed "Argentine" ant (*Iridomyrmex humilis*), nearly eliminated the fire ant altogether in the course of a fierce competition.



Caring for young. workers move larvae, *above*, and both larvae and pupae, *below*, in nest galleries. When a nest is broken open, workers move young deeper into tunnels that may honeycomb the earth for a depth of as much as five feet.





Spread of fire ants from about 1918, when they were first seen in Mobile, is shown by solid lines. The broken lines trace limits of secondary populations.

In 1928, another entomologist, William S. Creighton, visited Mobile and made some interesting observations of his own about the struggling population. He found that the ants were still limited to Mobile but had, in a few years, spread from the center of the city to the suburban community of Spring Hill. Creighton, an outstanding authority on North American ants with a special interest in fire ants, quickly grasped the significance of the situation, and warned that the imported ants appeared by now to be well established and might eventually spread to pest proportions. Had his advice been heeded in time, the South could have been saved millions of dollars in agricultural damage, for early in the 1930's, the Mobile population "exploded." Today, dense and growing populations reach from Texas to North Carolina.

Where did the imported fire ant come from? Creighton was the first to identify it correctly as *Solenopsis saevissima*, a species native to South America. On its native continent, it occupies a vast range extending from the Guianas to Argentina, and within this area, it shows extensive racial variation in color, size, and other external features. Since the population introduced into the United States has features typical of native populations in Argentina and Uruguay in size, color, and other external characteristics, it has been concluded that the original importation was from Buenos Aires or Montevideo.

The nature and control of biological invasions, of which the fire ant invasion forms a classic example, is today considered one of the outstanding problems of evolutionary biology. Why do some species of plants and animals flourish in new environments, while others quickly die out in these same places? And why do successful imports frequently build up huge populations exceeding those of the native species, and then, with the passage of time, deflate to more normal proportions? Biologists have been able to supply only partial answers to these questions, and often they are forced to rely on guesswork more than on fact—which is why such cases as that of the imported fire ant deserve careful study.

There are several clues as to why the introduced fire ant population has behaved in the way described. It is an interesting fact that in its South American homeland, the ant is not abundant enough to be a serious pest, and no special efforts are expended to control it. Exactly the same situation holds for the three fire ant species that are native to the southern United States (*Solenopsis aurea, S. geminata*, and *S. xyloni*), which can occasionally become minor pests but at the present time are completely overshadowed by the invaders.

It is usual to explain *S. saevissima*'s "exotic pest" effect by pointing out that when a species such as the imported fire ant is introduced into a new country, it leaves behind, at least for a while, its natural predators, parasites, and competitors. If, therefore, the invader proves superior in competition with native species of its new environment, it can be expected to enter a period of rapid growth, as it makes maximum use of its resources. In short, its population "explodes."

This process can be expected to continue until the invader exhausts its resources, whether these involve food or merely living space, or until the native fauna and flora "adjust" by genetic adaptation to the competitive strain imposed by the invader.

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Fire ant mounds, which may occur as many as fifty to an acre, are seen in a Mississippi field. Mounds reach about three feet in diameter, a foot in height.

Ideally, the invader is eventually fitted into the natural communities by a continuing mutual adjustment between it and the native species. In the process, the inflated populations of the invader are reduced until, from the human point of view, they are no longer serious pests.

The imported fire ant is evidently a long way from this theoretical adjustment level. On the contrary, population growth still seems to be accelerating; and it would appear that the population explosion starting in the 1930's was brought about by an important genetic change which continues to exercise a dominant influence. When Löding and Creighton first observed the imported fire ant in the 1920's, the population consisted entirely of a dark brown form that was easy to match with a common racial variant found in Argentina and Uruguay. At about the time of the population explosion, a second form, reddish brown in color and smaller in size, made its appearance. It corresponded closely to a racial variant found in northern Argentina and southern Bolivia and very likely was introduced into the United States (independently of the dark form) from that part of the population range. By 1949, when I first studied the species, the light form was clearly outproducing the dark form and replacing it over most of its range. Because of this fact, I have presented the hypothesis that the appearance of the light form was necessary to achieve the population explosion: for some reason that is not yet entirely clear, the light form is well adapted to the environment of the southern United States, while the dark form is not.

The future of this remarkable pest in the United States is uncertain. If left to spread unhampered, it will probably come to occupy most of the southeastern United States. Since it is a species adapted primarily to tropical and warm temperate conditions, it is not likely to spread north much beyond its present limits in Tennessee and North Carolina. Furthermore, it is not apt to press westward much beyond the humid coastland of Texas. It could, however, become settled in parts of California, and quarantine regulations are clearly needed to prevent its being carried by highway traffic to this Pacific state.

Crop damage caused by fire ants may already exceed several million dollars. Shown above is damaged okra. Seed corn, *below*, was also attacked by ants.

Ruined cabbage stems are seen below. The fire ants' diet typically consists of small insects, but population crowding forces them to turn to crops for food.

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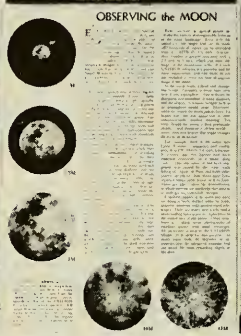
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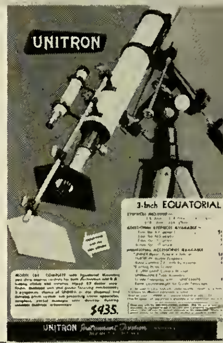
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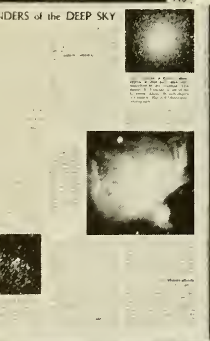
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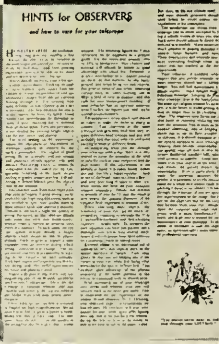
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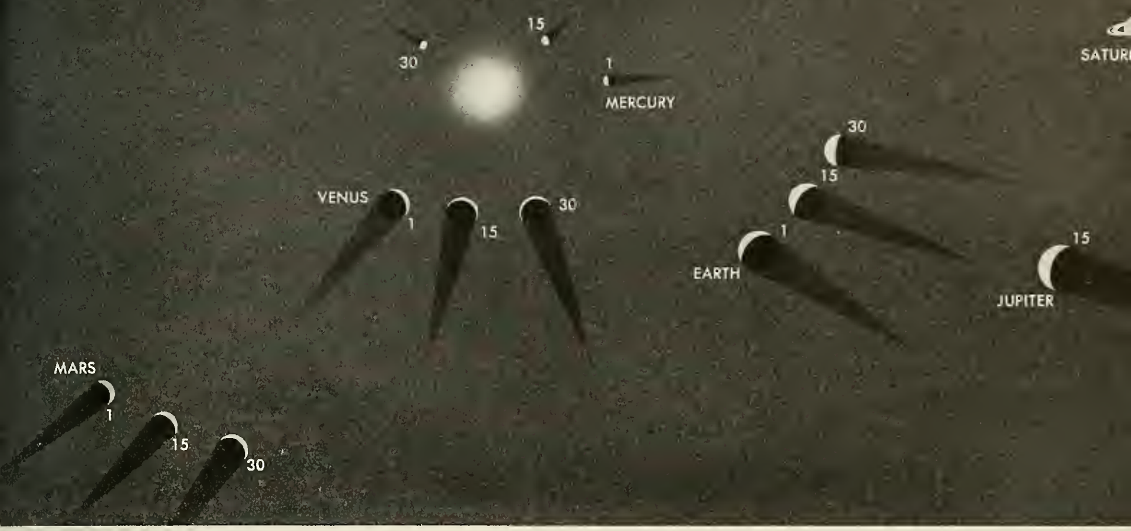
SKY REPORTER

By Henry M. Neely



THREE OF THE FIVE naked eye planets—VENUS, MARS and JUPITER—may be found on the star map this month. SATURN rises an hour and a quarter past map-time.

These planets' approximate positions relative to the earth and the sun are shown in the diagram, *above*, in which sizes and distances are, of course, not to scale. Noting their relative positions for the first of May, one might assume that MERCURY was far enough away from the sun to be clearly visible from the earth before sunrise.

That is true—but not in the Northern Hemisphere. If we could look at the whole solar system edgewise, instead of from above, we would see that MERCURY, during the first week of May, is quite far south of the line from the earth to the sun. For observers at about latitude 40° N., MERCURY will rise only about forty-eight minutes before sunrise and the dawn sky will be too bright for us to see it. But at latitude 40° S., where autumn is ending and the long nights of winter are approaching, the sun rises nearly two hours later and MERCURY, rising more than two hours before sunrise, will be observable.

VENUS remains well clear of the sun as seen from the earth all this month. It is now a brilliant object over the horizon, between west and northwest, as the evening dusk deepens. VENUS' position is shown for May 15 on the star map on the following pages.

MARS will also be found on the star map, to the left of VENUS, near the position of the moon for May 12. The diagram, *above*, shows that the earth is leaving slower MARS far behind; the ruddy planet is no longer very bright.

Great JUPITER—much more brilliant than any star—now dominates our night sky. It appears over the horizon on the star map when southeast is turned to the bottom. During the month, the earth passes between JUPITER and the sun. The three objects will be in line on May 18, with the sun and the great planet on exactly opposite sides of the earth. Astronomers call this an "opposition."

The earth, traveling in its orbit more rapidly than JUPITER and SATURN, passes JUPITER this month and SATURN late next month. Although both of these outer planets continually move eastward around the sun, there is a period of time, before and after the earth passes them, when it appears that they move westward, opposite to the direction of their real motion, against the background of the distant stars. The effect is an illusion, of course, and the westward motion of JUPITER and SATURN is apparent, not real. Since it is opposite to their real eastward motion, it is described as "retrograde"—backward.

The earth passes JUPITER on May 18; the planet's retrograde motion began on March 18 and will continue to July 20. For SATURN, which the earth will pass on June 25, the westward—retrograde—motion began on April 16 and will continue until September 4. During the rest of the year, the two planets will be seen to move eastward across the celestial backdrop—the direction of their real motion.

DURING May, VENUS and MARS are well above the horizon in the west as darkness falls. They must, of course, be observed before they set. JUPITER and SATURN rise southeast later in the night. A timetable for these events throughout the month is given on the following page. Dates of the month are at the top; times, in ten-minute intervals, are at the left side. Locate the chosen date at the top, come down that vertical line until you meet the line for the planet. This will give you the hour in Daylight Saving Time.

MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this monthly feature for NATURAL HISTORY.

THIS month's map presents two features that are of special interest to the confirmed stargazer. First; the Milky Way is virtually out of the sky at map-time. Its winter branch is setting along the western horizon, while the summer branch is just beginning to emerge in the east.

The second feature challenges dedicated sky watchers, for the long, straggling and faint constellation of HYDRA is high enough above the horizon to be traced in its entirety by observers in our mid-latitudes. An hour before map-time, the dim stars of the monster's tail will be too low to see: an hour after map-time, the stars that form its head, in turn, are too near the horizon to be easily viewed.

The position of HYDRA shown on the map is first reached just before dawn in early January. Then it is reached at progressively earlier hours until the more convenient times this month. But do not try to trace dim HYDRA if there is much moonlight. The Big Dipper will always tell when HYDRA is best. Roll the map to bring the north horizon to the bottom. Find the bright star, ALIOTH, in the Dipper. Whenever ALIOTH is directly above the North Star, HYDRA will be in the position shown on the map.

This mythological creature figures in the famous tale of the twelve labors of Hercules. HYDRA, according to the myth, had nine heads, only one of which was immortal. If any of the others was cut off, two new ones at once grew in its place. But Hercules and his companion, Iolas, solved the problem: when Hercules struck off a head, Iolas promptly used a firebrand to burn out the roots. And so the fearsome HYDRA was finally slain.

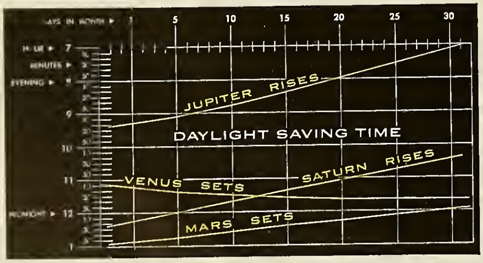
A brief calendar of events for this month follows.

May 1 to 10: The meteors known as the Eta Aquarids are due now, with a maximum on May 4. About 4:30 A.M., watch the sky 20° high between east and southeast.

May 11 to 20: An interesting stream of meteors radiates from near the star Zeta, at the top of the kite-shaped figure in HERCULES, throughout this period and for some days after. Locate Zeta over the east on the map.

May 21 to 31: Let the moon introduce you to SATURN on May 24. About midnight, the two will be side by side, 10° high in the southeast.

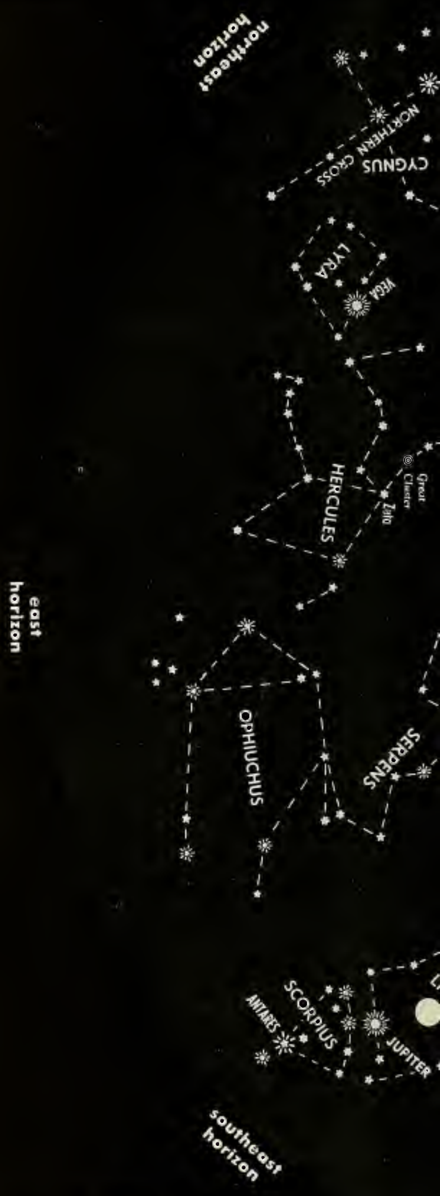
Predawn observers, on May 30, may look for meteors that radiate from above the Great Square of Pegasus, halfway up the sky over the eastern horizon.



HOURS IN MAY during which JUPITER and SATURN rise, while MARS and VENUS set, may be computed from the chart, *above*.

THE MOON'S PHASES

New Moon	May 7
First Quarter	May 15
Full Moon	May 22
Last Quarter	May 29

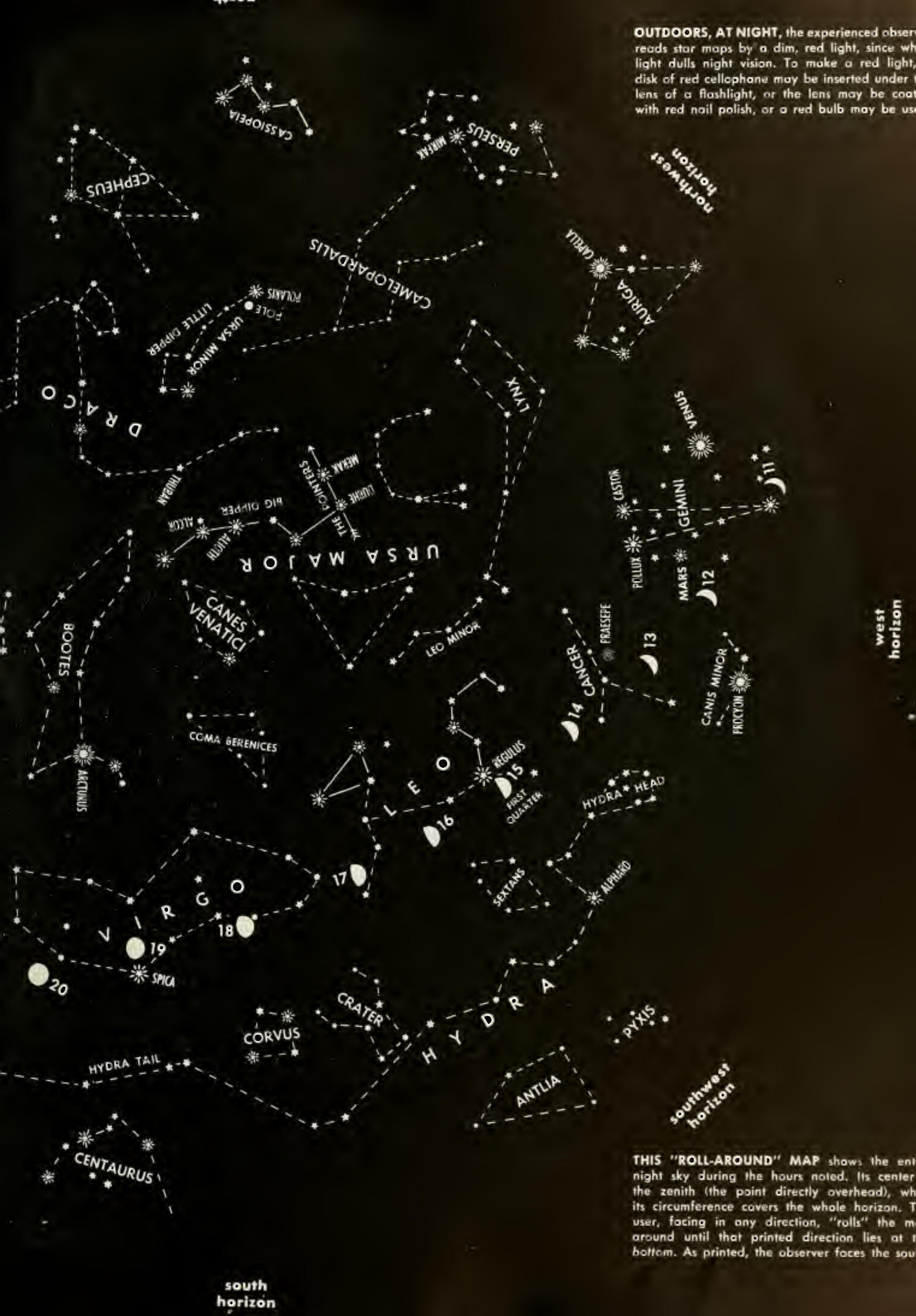


MAY TIMETABLE

First week	10:30 to 11.30 P.M.
Second week	10:05 to 11:05 P.M.
Third week	9:20 to 10:20 P.M.
Final week	dark to 9:45 P.M.

(times are Daylight Saving)

OUTDOORS, AT NIGHT, the experienced observer reads star maps by a dim, red light, since white light dulls night vision. To make a red light, a disk of red cellophane may be inserted under the lens of a flashlight, or the lens may be coated with red nail polish, or a red bulb may be used.


CASSIOPEIA
CEPHEUS
PERSEUS
MIRFAK
northwest horizon
CAMELOPARDALIS
CAPELLA
AURIGA
POLARIS
POLE
LITTLE DIPPER
URSA MINOR
DRACO
LYNX
VENUS
THUBAN
MERAK
DUBHE
THE POINTERS
BIG DIPPER
ALCOR
MIZAR
URSA MAJOR
CASTOR
GEMINI
11
POLLUX
MARS
12
CANES VENATICI
LEO MINOR
PRAESEPE
13
CANCER
CANIS MINOR
PROCYON
west horizon
BOOTES
14
COMA BERENICES
REGULUS
15
FIRST QUARTER
ARCTURUS
LEO
HYDRA HEAD
16
17
SEXTANS
ALPHARD
VIRGO
18
19
SPICA
20
CRATER
HYDRA
PYXIS
CORVUS
HYDRA TAIL
ANTLIA
southwest horizon
CENTAURUS
south horizon

THIS "ROLL-AROUND" MAP shows the entire night sky during the hours noted. Its center is the zenith (the point directly overhead), while its circumference covers the whole horizon. The user, facing in any direction, "rolls" the map around until that printed direction lies at the *bottom*. As printed, the observer faces the south.

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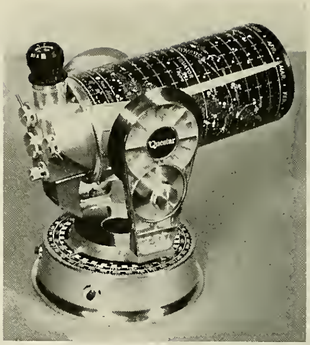

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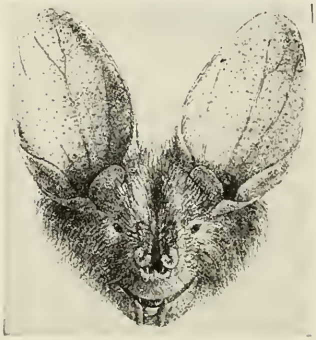
REVIEWS *(continued from page 246)*

Their lives differ in other ways, as well. Some roost in caves, others in the open, in hollow trees, or buildings, or in boulder heaps; some hunt in open fields, others in jungles; some fly a few feet from the ground, others at one hundred feet or more; a few have adapted to cold climates, most live in the tropics. They vary anatomically, also. Many bats have external nasal appendages, called nose-leaves, which may serve as beaming devices. The shape and size of their external ears vary markedly, as do wing shape and use, eye size and retinal anatomy. Many of these factors—differences in feeding and flight habits and in anatomy—interact with the practice of echolocation and have apparently altered its design.

Griffin also surveys echolocation as it is now known to occur in other vertebrates, including whales and two birds: the oil bird, *Steatornis*, a nocturnal, cave-dwelling bird of tropical America; and the cave swiftlet, *Collocalia*, a cave-nesting bird of Southeast Asia, one species of which produces the edible nest used in soup. The manner in which the blind now utilize sound for orientation, often unknowingly, is discussed by Griffin, as well as the probable future production of artificial devices for the blind that will utilize pulsed sound for obstacle detection.

All in all, this book provides an unusual opportunity. An outstanding scientist has here presented a record of his work in a field which combines the appeals of natural history, experimental biology, sensory physiology, and the physics of sound, in a manner which makes it rewarding reading for the layman, certain inspiration for the student, a permanent reference for the biologist, and a landmark for the sensory physiologist and mammalogist. Here is modern science at its best, impeccably and professionally presented, yet so clearly done that any intelligent reader will understand it. At the same time, we see a fusion of the descriptive and the experimental, the biological and the physical, the human and the electronic into a whole of very considerable beauty. If anyone is still ignorant of the aesthetic side of science, let him read Griffin's *Listening in the Dark.*



Nycteris macrotis

SEA SHELLS OF TROPICAL WEST AMERICA, by A. Myra Keen. *Stanford University Press, $12.50; 624 pp., illus.*

The Mexican shell-collecting grounds at Puerto Peñasco, San Felipe, Guaymas, Mazatlán and other points on the shores of the Gulf of California have long yielded bountiful conchological treasures. Although this fauna rivals the better-known fauna of tropical Florida and the West Indies in both richness and the number of colorful species, an illustrated handbook had not previously been available to students of the tropical west American shells. Dr. Keen's book meets this need at last.

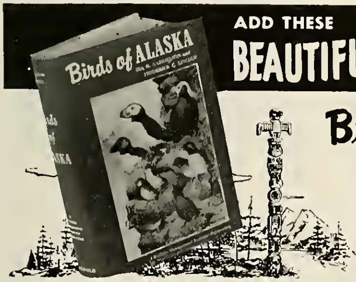
Most of the larger marine shells occurring from the Gulf of California to Colombia—the Panamic faunal province—are briefly described and are figured in nearly 3,000 illustrations, including ten handsome color plates. Notes on the geographic ranges of the species suggest where the collector might expect to find specimens. The use of nontechnical language, together with the inclusion of keys for identification, as well as a glossary, are intended to assist the amateur, while the more advanced student will find the extensive bibliography extremely useful. Students of American sea shells need no longer consider the tropical species of our Atlantic coast to be pre-eminent.

William K. Emerson
The American Museum

THE MOUNTAIN WORLD, edited by Malcolm Barnes. *Harper, $6.00; 208 pp., 52 plates.*

This splendidly illustrated book is one of a series produced under the direction of the Swiss Foundation for Alpine Research, the volumes of which are to appear every other year. It is a fine book and it deserves readers: but since it will have successors, perhaps there is particular usefulness in pointing out some flaws in the volume's planning and execution.

For one thing, its aim, we are told, is to present "the world's major mountaineering expeditions during recent



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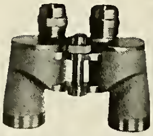

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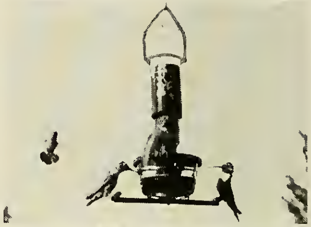

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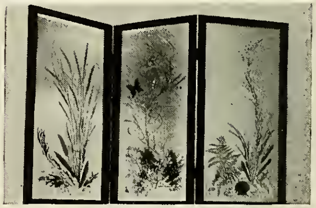

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months," yet this plan is not followed: some expeditions, like that of the Japanese Alpine Club to Manaslu, are long-term ventures extending over several years; and there is a chapter on the Eiger dealing largely with a series of stupid and disastrous attempts to conquer the peak in the late 1930's. But perhaps, in a book which appears only every other year, still less of an effort should be made to restrict the scope to recent events—especially since the feats in this period are of unequal caliber: it might have been better to abandon any attempt at topicality. In any case, consistency would be a merit. Then, too, some chapters are written in very awkward English; and in others, the structure is confused and the sequence of events unclear. Still in all, this is, to repeat, a fine book: the particular fusion of mysticism and very hard-headed, technical know-how one finds in the best climbing comes through. And the photographs are stunning. One wishes a somewhat revised "format," but one also wishes it success.

PETER FREUCHEN'S BOOK OF THE SEVEN SEAS, by Peter Freuchen with David Loth. *Julian Messner, $7.50; 512 pp., illus.*

THE seas not only make up some two-thirds of the earth's surface. They are also deeper than is the late Peter Freuchen's book, but hardly more capacious. He has produced an album of lore, authentic history, and speculation on almost everything that has to do with oceans. One might object to a few half-facts and unfinished explanations, but it does not matter: the book offers itself to all readers. There is a kind of open-handedness about it; and it is romantic and adventurous in a real sense. The clouds keep scudding ahead, and the reader follows with great pleasure.

This list details the photographer, artist, or other source of illustrations, by page.

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242-45—Courtesy Yale University Press.
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256-57—AMNH map; mosaic, Soil Conservation Service.
258—Eliot Blackwelder, top; James Fisher, bottom.
259—Richard Threet, left; courtesy McGraw-Hill, right.
260-61—Kenneth Gosner, after Richard Threet.
262-63—Josef Muench; except top, left—Cecil M. Ouellette.
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266-67—Wilfred Thesiger.
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270-71—Wilfred Thesiger.
272-73—Wilfred Thesiger; except bottom, center—Gavin Maxwell.
274-75—Wilfred Thesiger, top; Gavin Maxwell, bottom.
276—AMNH after Scientific American, top; AMNH after E. O. Wilson, bottom.
277-79—Ross E. Hutchins.
280—AMNH after Scientific American, top; Ross E. Hutchins, bottom.
281—U.S. Department of Agriculture.
283—Helmut Wimmer.
284-85—AMNH graph; sky map by Henry M. Neely.
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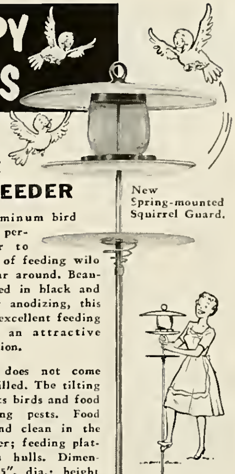
ERRATA: in credits for "Chemistry of Plant Growth," March, 1959, the photo across the bottom of pp. 148-49 should have been credited to R. J. Weaver. The photo by B. O. Phinney, listed for p. 152, actually appeared at the top of p. 148.

HAPPY BIRDS



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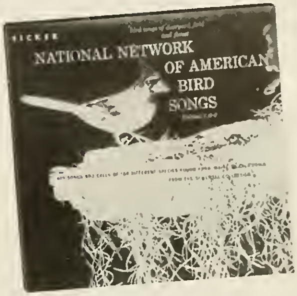

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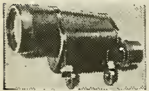

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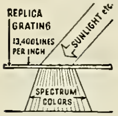

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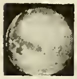

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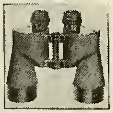

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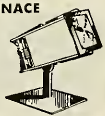

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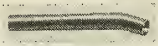

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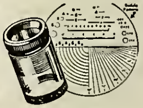

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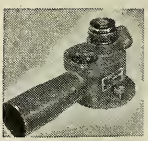

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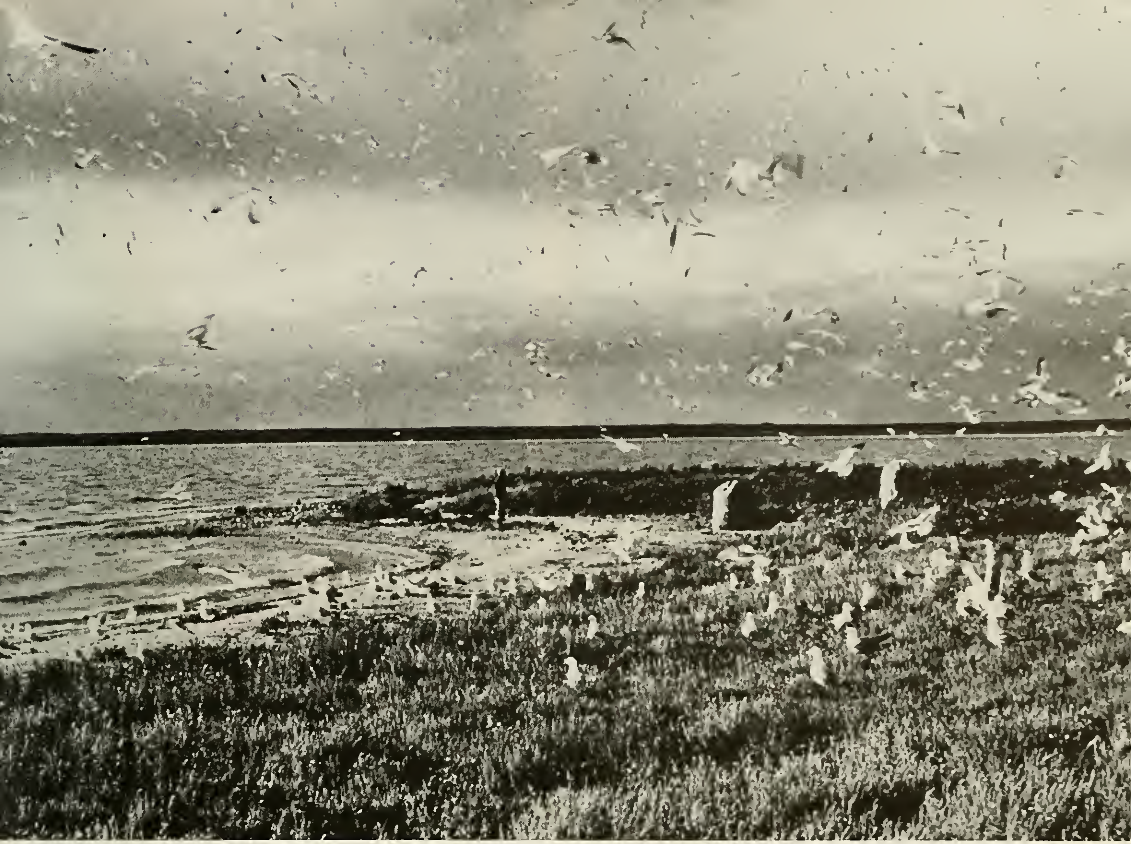


Dry-land nesting ground of western grebes, on Isle of Bays, in Saskatchewan, is shared with gulls, ducks, and other birds.

WESTERN GREBE COLONY

Found nesting on land, these water birds could be closely watched

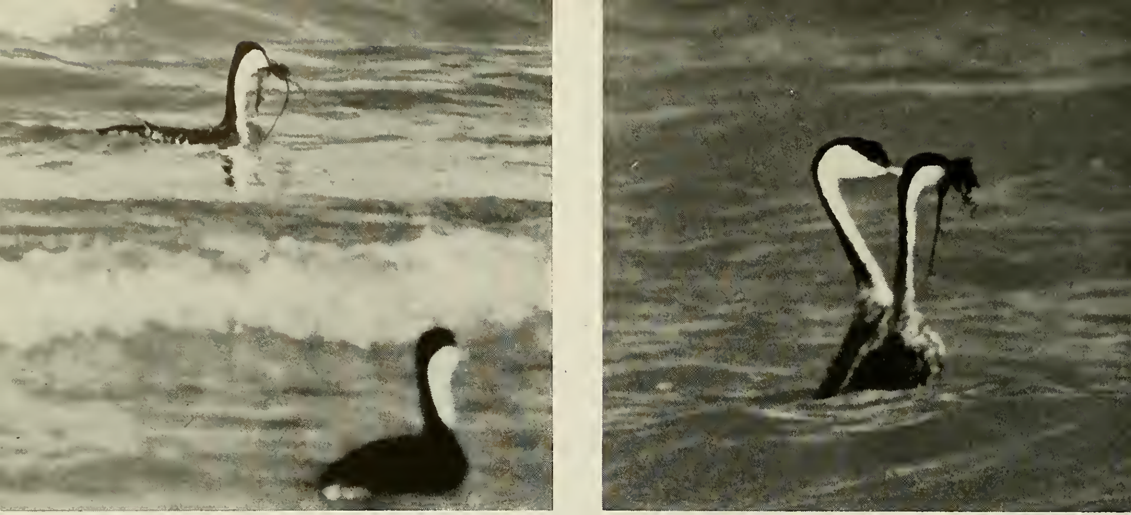
By Robert W. Nero   Photographs by Fred W. Lahrman

THE ISLE OF BAYS is a small island in the shallow, alkaline waters of Old Wives Lake, near Moose Jaw, in southern Saskatchewan. It was here that, recently, we came upon a colony of western grebes that, in variance with their usual habit, were nesting on dry land—either on the open ground or beneath rosebushes. This island offers a natural haven for nesting birds—thousands of ring-billed gulls, common terns, white pelicans, double-crested cormorants and ducks of several species nest in large numbers on the open areas or in the tangled vegetation that covers most of the island. But why should grebes, which are normally water birds, do so?

Tradition is a strong factor in the lives of birds. Old Wives Lake is subject to great fluctuations in water level. In earlier years, numerous western grebes nested, under usual conditions, in extensive bulrush beds which fringed the lake's shore. But in 1950-51, heavy runoffs brought the lake level up, flooding out the emergent vegetation and destroying the nesting habitat of hundreds of grebes. The same high waters covered the shores of the islands, partly submerging rosebushes and other land plants. The plants protruding above the water evidently offered a substitute nesting site, for grebes were observed nesting in this area in 1953. Although, in subsequent years, the water level in the lake went down, the grebes returned to the island's shores to nest, the bulrush beds not yet having reappeared. And, since it will probably be several years before the bulrush comes back, the grebes will likely return to the island each year until then.

We camped on the edge of one of

Dr. Nero, a Wisconsin native, holds the position of Assistant Director of the Saskatchewan Museum of Natural History. Mr. Lahrman is an artist and taxidermist at the same museum.



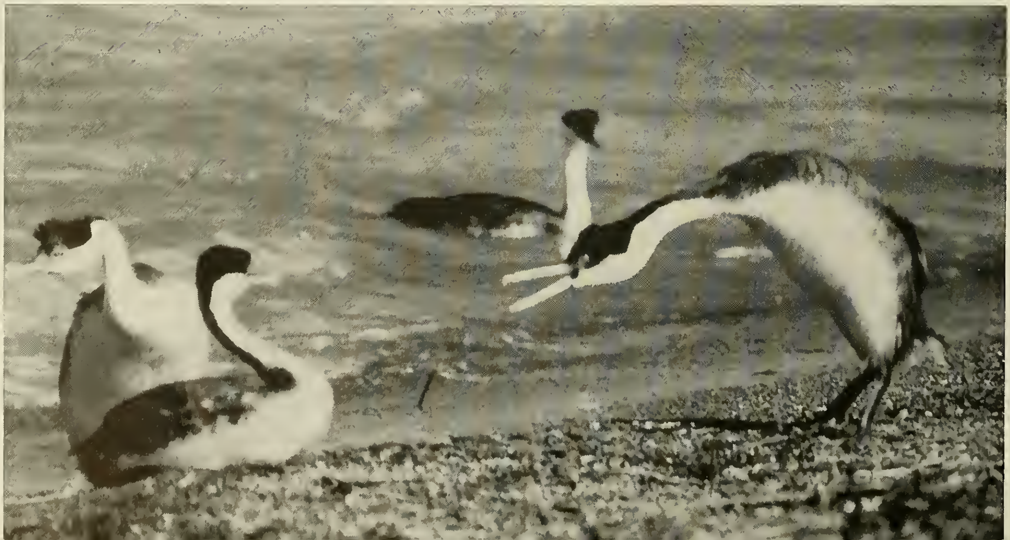
Grebes' courtship, preluding actual building of the nest, mating, and egg-laying, is the striking ceremony seen above from left to right, and called mutual presentation. Pair of birds, each holding beakful of water weeds (from which nest

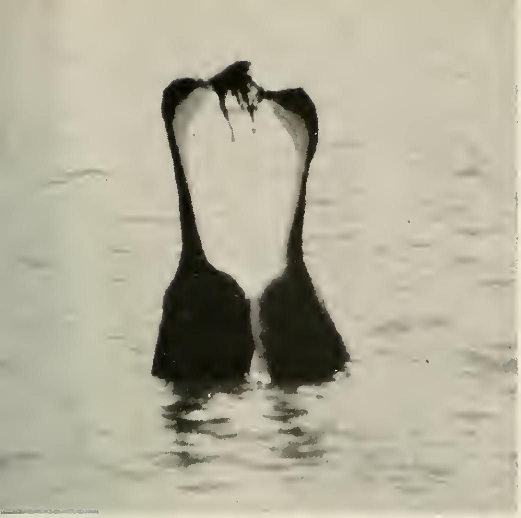
the many bays from which the island draws its name for two weeks in July and August, 1957, and employed the greater part of each day observing grebes in action—grebes fishing, loafing, courting and "dancing" on the offshore waters. Since our blinds were set near the nesting colony and close to the shoreline, we could watch them both in the water and in their nests, as well as coming and going overland.

At close range, we noticed these adept swimmers approach the edge of the beach, lurch to their feet and, after a moment's hesitation, walk, or sometimes run, across several yards of sand and gravel beach to their respective nests. Their adroitness on land was a continual wonder to us—though awkward in gait, they appeared agile and capable. The long feet, with their flattened, leaflike toes, are placed far back on their bodies for efficiency in swimming; yet at times these birds even stood upright and motionless for a few minutes. Nevertheless, they were obviously enduring considerable discomfort as a result of a life on land and in the hot sun—some of the grebes we captured had dry, cracked and scaly toes, probably from being so long out of water. They were also frequently attacked by common terns while crossing the beach to reach their nests. Sometimes, the grebes were actually knocked sprawling by the aggressive assaults of these sharp-billed tyrants.

Although there were sometimes hundreds of grebes swimming offshore, the associative behavior of many couples revealed them to be "paired" birds. Physically, too, the sexes were readily distinguishable, males

Grebes' mating begins, in this case, as one male threatens another seen (left, rear) behind female. Grebes were forced to mate on dry land when rising water submerged bulrushes along lake's shore, which had provided usual mating ground.





is made), draw near each other; then, in silence and face to face, they rise higher and higher above lake's surface, until at last their breasts and beaks touch in a majestic display. After this, the grebes sink back and resume their swimming.

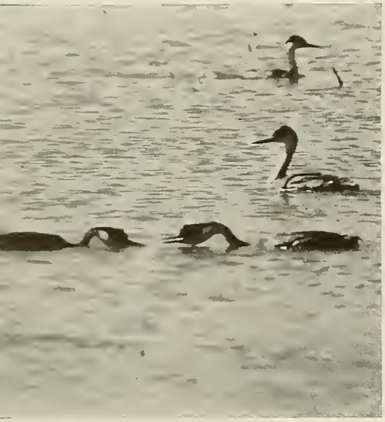
being larger than females, and with a heavier and stouter beak. Frequently, couples simply swam along or rested side by side; often, the male emerged from below the water with a fish held in his beak and offered it to the female, which took it from him. Such "courtship feeding" is common to many species during the early part of the breeding period.

A gesture of preening the plumage was also commonly seen. This, too, appeared as a ritual display, given in very stereotyped fashion. Comfort preening became "mutual bob-preening," both birds holding their heads high and reaching back to pluck at their back or wing feathers, then immediately returning to the head-high position. This would be repeated several times and was frequently seen to occur among couples.

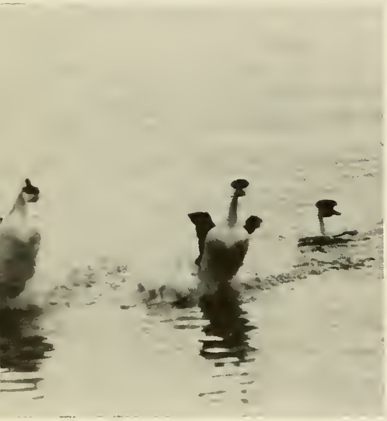
OFTEN, a pair would swim along with the male in the lead in "high-arch," holding his head up high with beak pointing downward. Upon occasion, they approached the shore and indulged in ritual display evidently associated with selection of a nest site and high sexual excitement: the male usually—but sometimes the female—dipping his beak in the water up to the nostrils and then holding it rather stiffly in that position for several seconds while the other member of the pair looked on. When the female performed thus, her back feathers were usually held erect.

On other occasions, one bird would dive, emerge with a mass of water weeds in its beak and swim about holding this sodden load aloft as if with great pride. This often led to a mutual presentation of nest-material

THE PAIR OF GREBES is finally left alone before mating. Firm footing of land seemed to offer suitable substitute for the elevated platform of nests usually built in reeds, although birds are gradually returning to their old nesting habitat.



Aggressive display between two males begins grebes' "water dance," or "run."



Wings outspread, grebes pound water with feet as they break into the "run."

After a "run," birds settle back into water and preen feathers or turn heads.

(for of such is the nest usually made), both members of a pair holding a beakful of weeds while rapidly approaching each other, then silently, while facing each other, rising higher and higher out of the water; finally, in a strikingly impressive ceremony, they touch breasts and bring their beaks together, for several seconds resting against each other, while literally standing on top of the water. Then they gradually sink down and resume swimming or loafing together. This unusual behavior is apparently the "true courtship" of the western grebe, leading to actual nest-building, mating and egg-laying.

The nest is built by both sexes, although the female plays the larger role in arrangement of the material at the nest. We noticed attempts to add material to the nest after incubation had begun; presumably, this is necessary in the case of nests built in water in order to maintain the height of the platform, but this would not be the same for nests on land. Nevertheless, habit persists, and our land-nesting grebes were frequently observed vainly attempting to pull loose a branch from a rosebush. Both sexes also take turns incubating the eggs—with the female again seeming to spend the most time on the eggs. The "brood-patch," an area on the abdomen from which feathers are removed, thus permitting closer contact between body and eggs, is conspicuous in both sexes in the western grebe.

The western grebe's spectacular "water dance," "race," or "run" seems to be less directly related to courtship than to a kind of social ceremony arising from and permitting the release of nervous energy. The grebes we watched appeared recklessly aggressive, stabbing at every species of duck encountered and frequently going beneath the water to pull or pluck at the feet of the passing parade of waterfowl; a sudden fit of energetic splashing by a previously drowsing canvasback was usually the signal for a grebe to bob up suddenly nearby. Similarly, grebes frequently made aggressive gestures to other grebes, but we never saw any direct contact of an aggressive nature between them. Such bouts of aggressive display of a clearly ritualistic nature invariably preceded their "runs." (Usually, only two grebes faced each other in this manner, but sometimes others became involved. Most often, the couples were of mixed sex, but about a third of the more than eighty "runs" we recorded consisted of male-male couples. About half of the male-female couples which we observed running were actually paired birds, that is, sexual mates.

At any rate, the grebes then swam rapidly toward each other with throats distended, eyes bulging, crests erect, meanwhile emitting a harsh clicking or buzzing sound. This "menacing" behavior was alternated with "mutual dip-shaking," whereby the beak was dipped into the water and then the head quickly raised and the beak flipped from side to side. "Threat-pointing" and "dip-shaking" continue until the birds are nearly touching beaks, then they suddenly go directly into the "run," both birds turning at a right angle and dashing off side by side. The wings are held partly outspread while they run; the pounding feet produce a roar like a motor. Sometimes the grebes run for fifty to one hundred feet, in the end suddenly diving into the water. Invariably, they emerged after the dive with heads held high and stiff, approaching each other and rising higher and higher in the water, or else "treading," turning sideways to each other and, when close, beginning to stiffly turn their heads and beaks toward each other and then abruptly away and then back again, meanwhile giving a most peculiar high-pitched and plaintive, long-drawn-out whistle like that of a boiling teakettle.

Gradually, all this subsides and finally the two birds drift apart or, if a pair, slowly swim along together. The entire sequence of the "run" has been observed throughout the breeding period; some observers have even seen as many as seven birds participating! No matter how many times we saw it happen, each new occurrence excited us; the sudden, harsh clicking call of a pair suddenly "threat-pointing" brought about a frantic effort to focus our "glasses." At such moments the observer is magically transported from the dark confines of the hot and humid blind to far out on the cool water with the wild, dashing western grebes.

Climax of "run" shows birds skimming lake. "Run" may extend a hundred feet.

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No. 6

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June-July 1959

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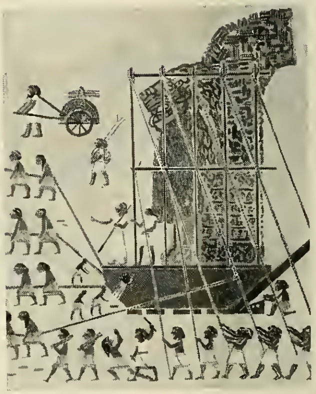

The cover for this issue was especially painted for Natural History by the artist Hans Guggenheim, who traveled widely in Anatolia and became particularly interested in the ruins of Hattusha, ancient capital of the Hittites. Owing to the hospitality of the Turkish government, more and more is becoming known about this remarkably sophisticated culture that flourished in Anatolia between the seventeenth and eighteenth centuries B.C. Studies of the records found in the royal archives of the Hittites have revealed intimate details of their daily life, their rituals, and even their court gossip, as well as their legal concepts and their broad political influence. For an account of these heterogeneous and influential peoples, who left their mark on early culture throughout all the Middle East, turn to page 308.

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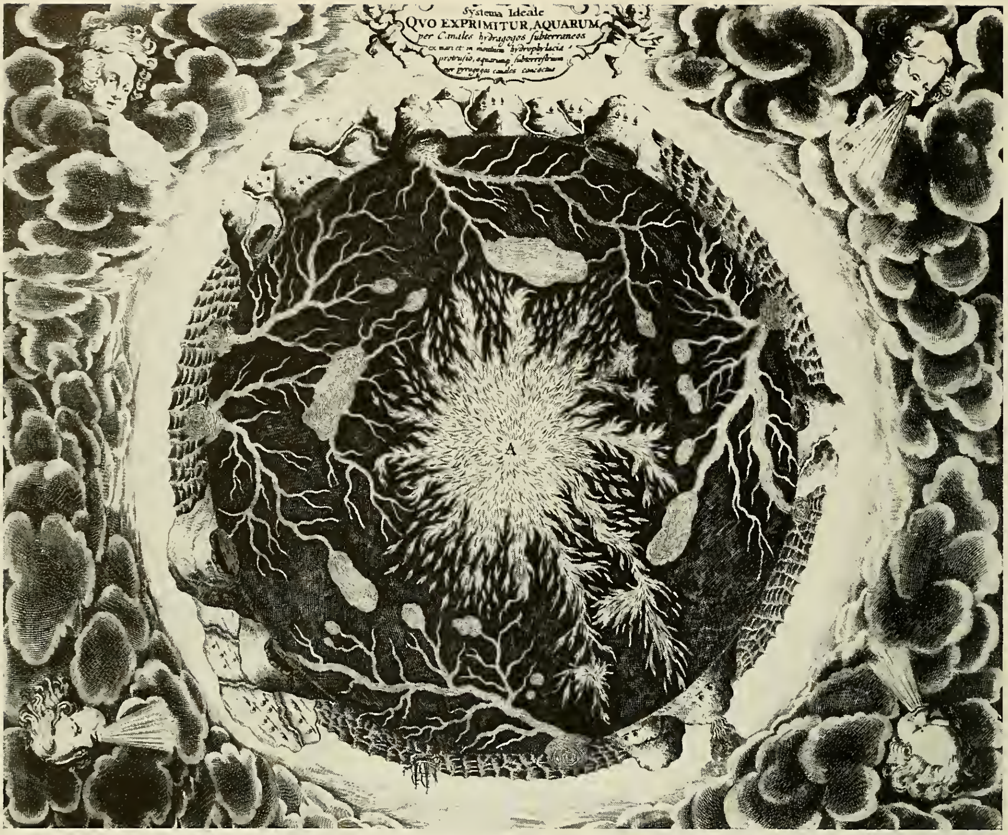
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A

Cross section of the earth, with central fire, was concept of the seventeenth-century scholar Kircher. Illustration from Adams.

Reviews

PAPERBACK BOOKS WITH A PURPOSE

Reviewed by Christopher Gerould

THE PRISMATIC DISPLAY of flesh on newsstands and in drugstores often obscures the fact that the paperback book trade, today, has a lot more to offer than excursions in applied sadism or quick trips to the asteroid belt.

With the phenomenal success of their fiction titles over the last twenty years, many of the paperbook publishers have been encouraged to add nonfiction titles to their lists; and the popular success of these "unpopular" items has, in turn, stimulated other publishers to venture into the paperbound field with an extraordinary variety of serious books, both in reprint and as originals.

The average reader, as a result, has in many ways never had it so good. For if he wants to pass by the Spillanes and the Erle Stanley Gardners, he can find solid titles for his personal library — all the way from Plato to Darwin — at a half to a twentieth of the price of the same titles in hard covers.

One could wish that all paperbacks cost a quarter, but failing that impossibility, one can be more than grateful for the many paperbacks that cost more than a quarter—but are still comparatively inexpensive and have good printing and bookmaking to offer, as well as good texts inside their paper covers.

According to the latest issue of the useful survey *Paperbound Books in Print* (R. R. Bowker, $2.00; also available, as a subject index alone, for 25¢), some 6,000 paperbacks are now in print. Many of these should be of interest to readers of Natural History. This article is limited to only sixty-nine titles and is frankly intended as hors d'œuvres. Readers can then go on to choose their own main dishes and desserts from the Bowker index.

If there is a standard of quality in paperbacks, it would almost certainly be the British Penguins. The Pelican series, published by Penguin, probably contains more natural history than any other series on publisher's list.

Typical is *Watching Birds*, by James Fisher (Pelican, 65¢). Here a professional ornithologist treats bird watching less as a hobby in itself than as a first step into a field of science where amateurs can make and have made valuable contributions. Mr. Fisher's book is written, naturally, about birds that can be watched in the British Isles, but much

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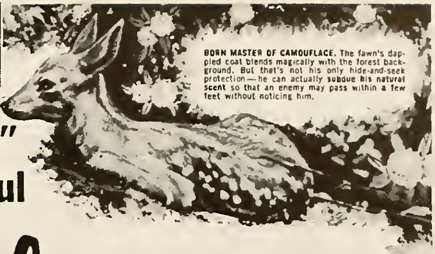
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MR. GEROULD, who reviews regularly for NATURAL HISTORY, reports here on a specialized field of publishing.

of his material on bird anatomy, classification, and behavior is applicable anywhere, while his general program and specific tips for the bird watcher point the way to intelligent and productive observation, based on the knowledge of what is important to watch.

The result of this kind of observation is contained in *The Life of the Robin*, by David Lack (PELICAN, 65¢), where the author has gathered together virtually all the known data on "Britain's most popular bird" into what amounts to a complete natural history of the genus. Here again, the book has much to interest American bird lovers, though *Erithacus rubecula melophilus* never visits this continent.

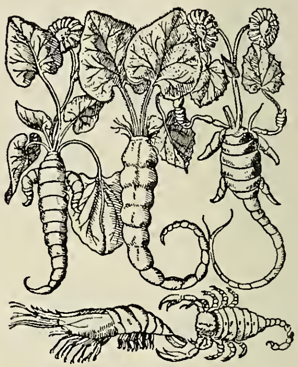
Another peculiarly British animal is the subject of *The Badger*, by Ernest Neal (PELICAN, 85¢). Mr. Neal's study is based very largely on his own years of observation of this shy and fascinating subject, and his memories of nights in the woods watching badger sets or dens effectively communicate his enthusiasm.

The Ant World, by Derek Wragge Morley (PELICAN, 65¢), covers once again one of the most written-up groups in the animal kingdom. Ants are perennially interesting, and new and extraordinary patterns of life and behavior are still being discovered among the 15,000-odd species, to which this book is a good introduction.

The Darwin centennial has brought a flood of books about Darwin and about evolution. *The Theory of Evolution*, by John Maynard Smith (PELICAN, 85¢), is a popularization in the best sense, bringing evolutionary theory up to the present day, and showing the mass of scientific evidence that has accumulated to reinforce and extend Darwin's original theory. This book puts demands on the reader's powers of concentration, as does any adult and thorough treatment of a complex subject.

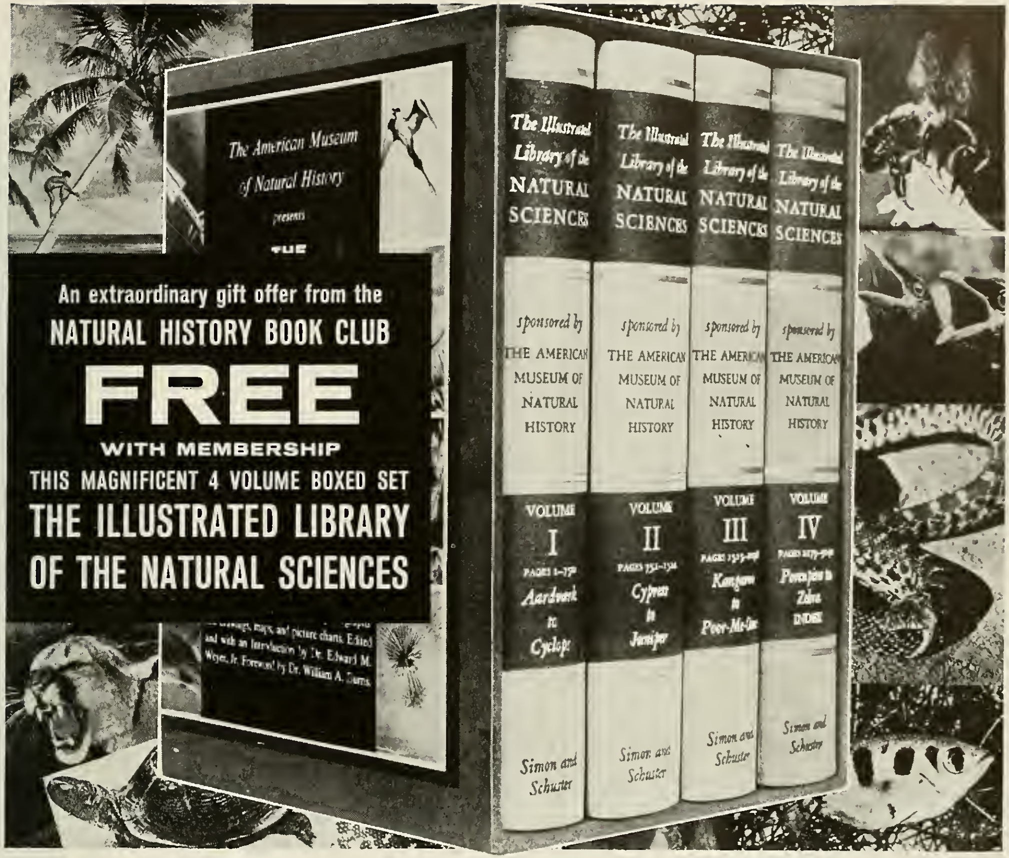
TWO reference works, both for beginners, are of another type, and good value for the money. These are *A Dictionary of Biology*, by M. Abercrombie, C. J. Hickman, and M. L. Johnson (PENGUIN, 65¢), and *A Dictionary of Science*, by E. B. Ubarov and D. R. Chapman (PENGUIN, 65¢). Covering approximately 1,500 technical terms each, both dictionaries can be very helpful to the layman brought up abruptly by some important but arcane technical term. He will sometimes have to chase the meaning back through several interlocking definitions, but he will ultimately get there.

THE last decades have seen an extraordinary growth of interest in a previously neglected field – the history of science. To the layman, the better books in the field offer a particular attraction since they enable him to approach and appreciate the complexities of modern science by gaining an understanding of the foundations that underlie it and seeing how these foundations were built. Among a number of good paperbacks in the general field, *Medieval and Early Modern Science*, by A. C. Crombie (DOUBLEDAY, 2 vols., $1.90), is one of the more readable and interesting. Covering the fifth to the seventeenth centuries, it throws much light on the indirect transmission of Greek science to Western Europe via the Arab world, and incidentally shows how much of the groundwork was laid in the supposedly dark ages for the shining accomplishments of Galileo, Copernicus, and their contemporaries of the sixteenth and seventeenth centuries. Then, as later, the scientific discoverer "stood on the shoulders of giants." Crombie's work covers virtually the whole of science from mathematics to medicine, and is particularly interesting in its accounts of the abilities of medieval physicians, and surgeons.


LIKENESS of aconite root to Arthropoda.

Two specialized histories, both classics of scholarship, are far more entertaining than their titles might indicate. *The Birth and Development of the Geological Sciences*, by Frank Dawson Adams (DOVER, $2.00), starts with the very earliest notions of the Greeks and carries the development of the earth sciences up to modern times. Well-illustrated and with an ample text, the book discusses in detail the work of more than three hundred individual geologists. J. L. E. Dreyer's *A History of Astronomy from Thales to Kepler* (DOVER, $1.98) leads from the Greeks to the beginnings of modern astronomy, with particular emphasis on the problem of understanding our own planetary system.

(Continued on page 354)



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The Timely Grunion

This fish's spawning follows tidal cycles with uncanny precision

By Boyd W. Walker

THE LIVES of many animals reveal a spectacular, and spectacularly precise, timing: certain actions are performed and certain cycles completed according to a rigid periodicity, regulated by a mechanism we do not fully understand.

The grunion, a small, pelagic fish, is one such creature. On most beaches of southern California, between March and August, at each full or new moon as the high spring tides occur, the grunion can be seen running on the beaches where they spawn. Within approximately thirty minutes of the highest tide, they deposit their eggs and return to sea with the receding waves. The fertilized eggs develop in the sand, and when the waters of the next spring tide again submerge the beach, the newly hatched grunion swim out to sea.

Grunion were reported on southern California beaches as far back as 1860, but were neither rare enough to excite collectors nor numerous enough to be commercially valuable. The first accounts of grunion spawning were so cluttered with theories on the effects of moon, tide, "race suicide" and other factors that they were generally dismissed as fishermen's yarns.

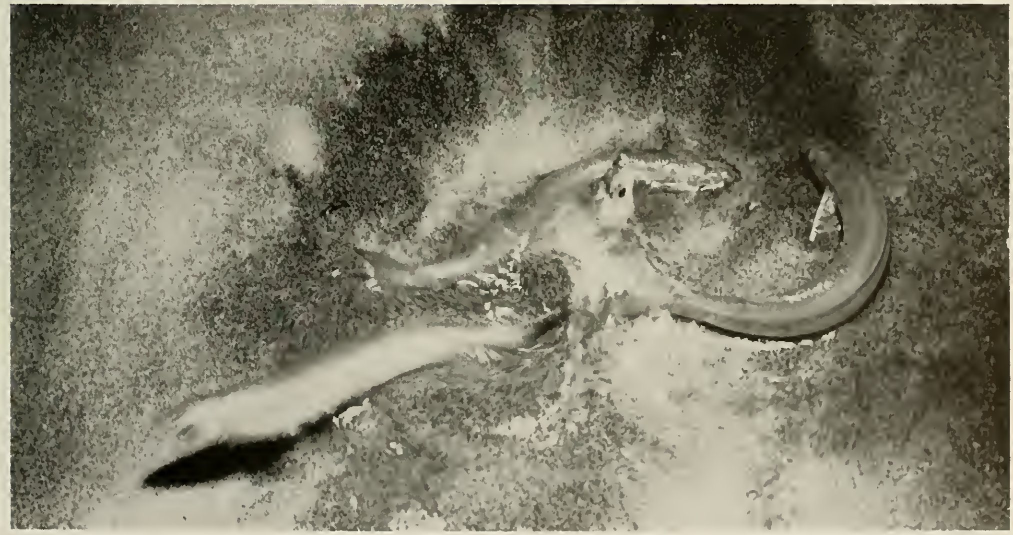
It was not until 1919, when Dr. Will F. Thompson, assisted by J. B. Thompson, published in the California Fish and Game Commission *Bulletin*, a fine account of the spawning of grunion, that their life story was clearly set forth. Subsequent research by Dr. Frances N. Clark and myself has provided additional information, and the delicate adjustment between the life cycle of these fish and the action of the tides now attracts much scientific speculation.

The grunion is slender and sardine-sized, averaging five to six inches in length, with a bluish-green back and bright silvery sides and belly. Its scientific name is *Leuresthes tenuis*, and it belongs to the family Atherinidae—the atherines, or silversides, are primarily fishes of tropical and temperate seas. The grunion's nearest relatives on the Pacific Coast are the jack smelt and top smelt, two important market fish caught in California waters.

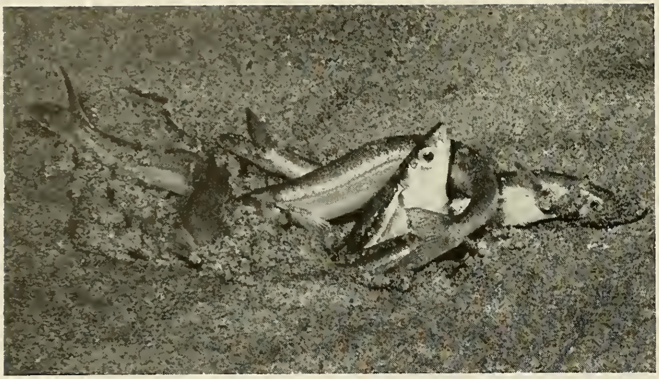
Dr. Walker, an associate professor of zoology at UCLA, has long been a student of *Leuresthes tenuis*. He has published his grunion findings in the journal *California Fish and Game*.

GRUNION are found nowhere else in the world. Their principal range is between Point Conception (just above Santa Barbara) to Punta Abreojos in Baja California—a coastal stretch of approximately 300 miles. Small populations of the fish do, however, exist north and south of this range—for example, occasional grunion have been found even as far north as Monterey Bay.

To a zoologist, the most interesting thing about the grunion is not the sport they have created on southern



Spawning on the beach, these grunion, *left*, form vast sheet of silver in the night. *Above*, female, surrounded by three males, is seen in center of the photo with her head sticking out of the sand, into which she has dug herself with her tail.



Deep in sand, female lays her eggs as males discharge milt on beach around her. If no males are about, the female will return to sea with outgoing wave.

California beaches, but the unusual spawning habits already mentioned.

The California grunion spawning season, then, lasts six months—from early March to August, its length varying slightly from year to year. Early in January, the gonads, or reproductive organs, of the fishes start to swell, and by early March the first batch of eggs is matured, their time of maturing being somehow adjusted so that the eggs are ready to be spawned just at the time of the high tide series. For the remainder of the spawning season, the female ripens successive batches of eggs at intervals of about two weeks. Actual spawning is restricted to a relatively few hours on three or four nights following each full moon or new moon, and then only for a one- to three-hour period immediately after high tide.

The spawning run is heralded by a few lone scouts (usually males) that swim in with a wave. Occasionally, one is left on the beach after the wave retreats. Gradually, more and more fish come in and, by swimming against the outflowing water, strand themselves on the beach until another wave washes over them. Spawning usually starts about twenty minutes after the first fish arrive, reaching a peak of activity about an hour after the start of the run and lasting from thirty to sixty minutes, on the average.

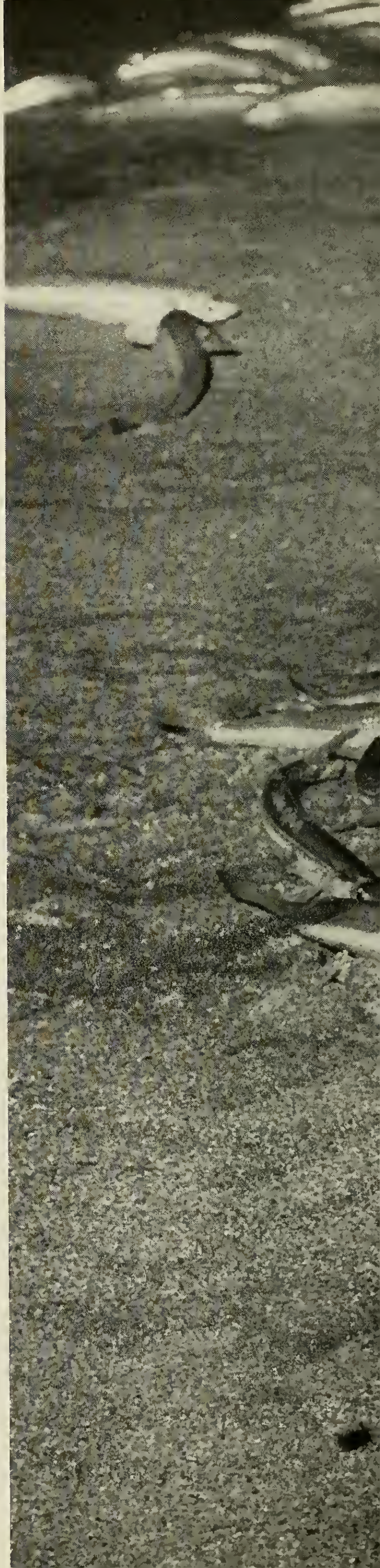
During a good run, thousands of fish may be flopping on the wet sand at one time, turning it into a vast sheet of shimmering silver. While the run usually lasts from one to three hours, the number of fish on the beach at any instant varies from none to multitudes. Finally, when the tide has dropped a foot or more, the run slackens and then stops as suddenly as it started. No more fish will be seen that night, and they will not appear again until the next night or the next series of runs.

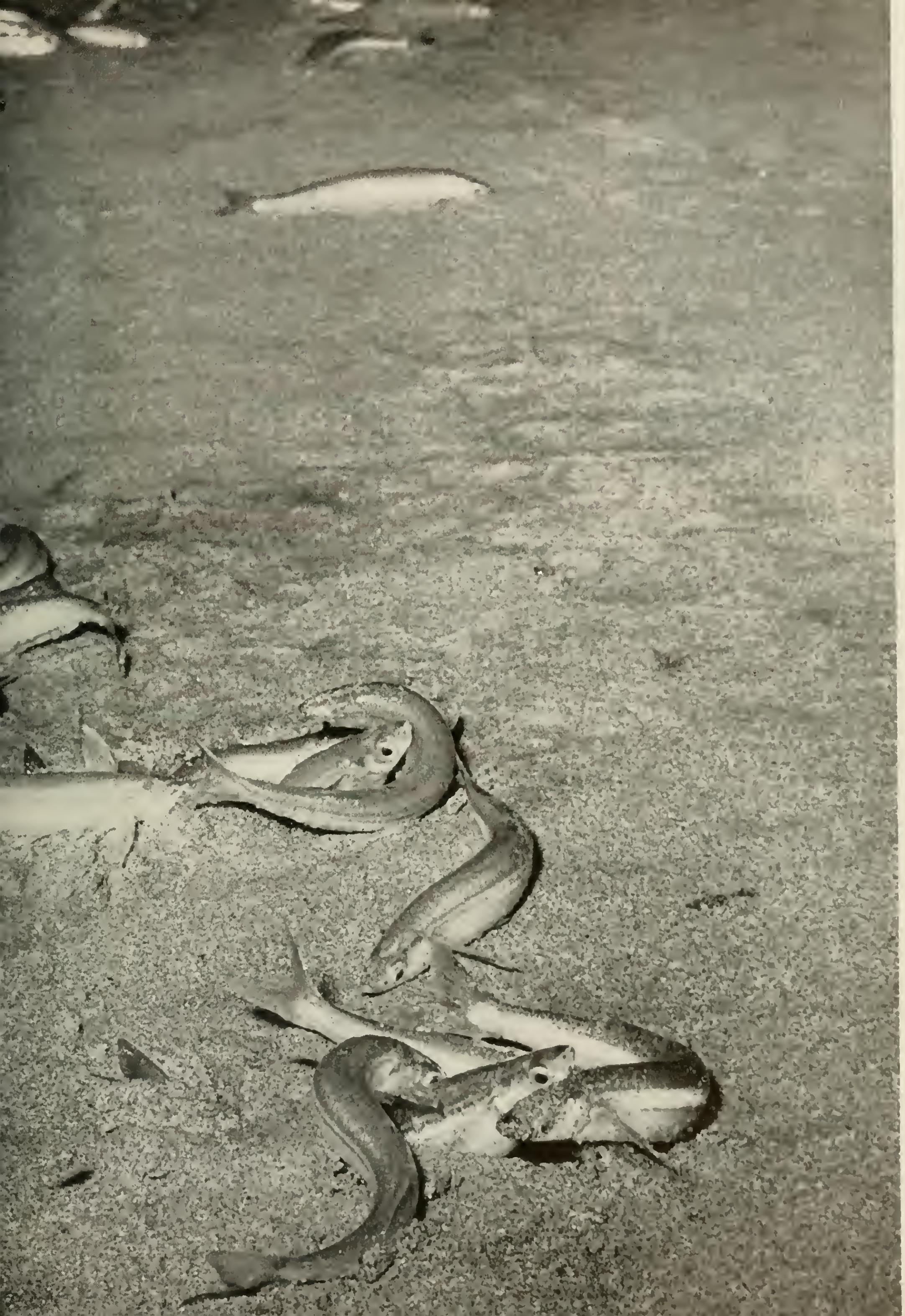
The actual mating of the grunion is rapid. The female swims onto the beach accompanied by one or more males: as many as eight males have been observed mating—or attempting to mate—with one female. If, on the other hand, no males are present, the female will return to the ocean with the outflowing wave; but if they are present, she swims as far up on the beach as possible, where she digs herself into the sand as the wave recedes. This is accomplished by arching the body with the head up, and at the same time vigorously wriggling the tail back and forth.

As her tail sinks into the semifluid sand, the female twists her body and literally drills herself downward until she is buried up to the pectoral fins. She may even bury herself completely.

The male, or males, curve around her as they lie horizontally on top of the sand, with their vents close to or touching her body. The female, continuing her twisting, emits her eggs two or three inches below the surface of the sand. The males discharge their milt on the sand near the female, and then immediately start to wriggle toward the water. The milt flows down

Brief mating, at right, may last only thirty seconds, including the digging-in.





Spawning records on the grunion are kept by team of UCLA biologists, *above.*

around the body of the female, fertilizing the eggs in the sand.

The spent and tired female then frees herself from the sand and returns to the sea with the next wave that reaches her. The actual process of digging-in and egg-laying may take only about thirty seconds, but individual fish may stay on the beach for as long as several minutes.

The females spawn four to eight times during the season, on consecutive runs. The number of their eggs varies with the size of the fish: large females produce about 3,000 eggs every two weeks, small fish produce about 1,000. During the early part of the season, only the older females spawn, but gradually the fish born the previous year come into breeding condition, and during April and May fish of all ages spawn. After these two months, spawning diminishes.

The eggs, which are deposited about two inches below the surface of the beach by the female grunion, are buried still deeper under sand deposited by the outgoing tide. Succeeding lower tides leave the eggs covered by eight to sixteen inches of sand. Here they remain—out of water but in moist sand—for about ten days, until the next series of high tides erodes the beach and washes them out of the sand. Two or three minutes after the eggs are freed, the baby grunion hatch and are washed out to sea.

The habits and timing of the grunion are adapted to the tidal cycles in a wonderfully precise manner, involving several complicating factors. For one thing, the heights of the tides vary according to the position of the moon—the highest tides occurring when the moon is new or full. Also, along the Pacific Coast, the heights of the two daily high tides vary, with the higher tides occurring, during the spring and summer months, at night. The grunion spawn only on these higher tides, and after the tide has started to recede.

Then, too, since the waves tend to erode sand from the beach as the tide rises, and deposit sand as the tide falls, it is obvious that if the grunion spawned on a rising tide the eggs would be washed out by succeeding waves. This danger is averted by the fact that spawning is usually confined to the falling tide.

Furthermore, the grunion almost always spawn on a descending tide series, when succeeding tides are lower than those of the previous night—the eggs would be washed out if spawned on the ascending series.

Finally, the spawning must take place soon after the highest tides, if the eggs are to have sufficient time to develop before the next series of high tides washes them free.

From all this, we can see that there are only three or four nights each month when conditions are right for spawning. It is these that the grunion utilize. How is this timing controlled so exactly? As yet, we have no firm theories as to how such precision is achieved. The best guess is that it is caused by a combination of the tidal cycle and the diurnal cycle, which, in turn, produce an observed lunar cycle. The mechanism used by the fish to sense this cycle is not known at present, but apparently it is some kind of a tidal response.

The hatching of grunion eggs also shows a remarkable adaptation to the environment. They will not hatch until they are uncovered and agitated by the surf, but after such a stimulus, the process takes only a few minutes. Thus, the eggs cannot hatch prematurely in the sand, where the young fish would die. Upon reaching the surf, however, they hatch rapidly—reducing the time the fry must spend in this rough and dangerous area. If the eggs fail to be washed free, they can remain in the sand for another two weeks — they will still hatch if they are washed free in the following series of high tides.

The young fish grow rapidly and are about five inches long by the time they are one year old and ready to spawn. The normal life span of a grunion is two to three years—with an occasional individual living to the age of four. Growth is much slower after the first spawning in the grunion's life, and stops during the spawning period. This cessation causes a mark to form on each scale. By counting these marks, the age of the fish can be determined.

Some laboratory work has been done on the hatching of the grunion and a motion picture on the subject has been made. Here again, we do not know precisely what the mechanism is, but it is safe to assume that hatching is caused by a "hatching enzyme" released by agitation. I have kept eggs in containers where there was no agitation, with the result that no hatching occurred; similar containers, where agitation took place, produced normal hatching. It is even possible to see marked changes in the egg shell occurring during such agitation: at the beginning, the eggs are very tough, but within two to three minutes they become friable.

The development and hatching of grunion eggs can, incidentally, be induced artificially. One collects fertilized eggs by digging them out of the beach where spawning has been observed, or even stripping them from live fish and artificially fertilizing them. Eggs that have been spawned in the sand may be recognized because they are in salmon-pink clusters about five-eighths of an inch in diameter.

Fish ripe for stripping, on the other hand, are easily selected, since a light pressure on their sides causes eggs or milt to be extruded. The best method seems to be to strip the eggs into a dry dish or saucer, and then immediately strip the milt from several males in with them—mixing eggs and milt thoroughly. Then the eggs collected by either method should be buried in sand to a depth of about three inches. If the sand is kept moist with sea water, the eggs should be ready to hatch within ten days to two weeks. When they are placed in sea water and agitated, young grunion pop out within a few minutes. But raising the fry is difficult and probably doomed to failure unless a continuous supply of sea water is available. Even under these ideal conditions, they have never been kept alive longer than one month.

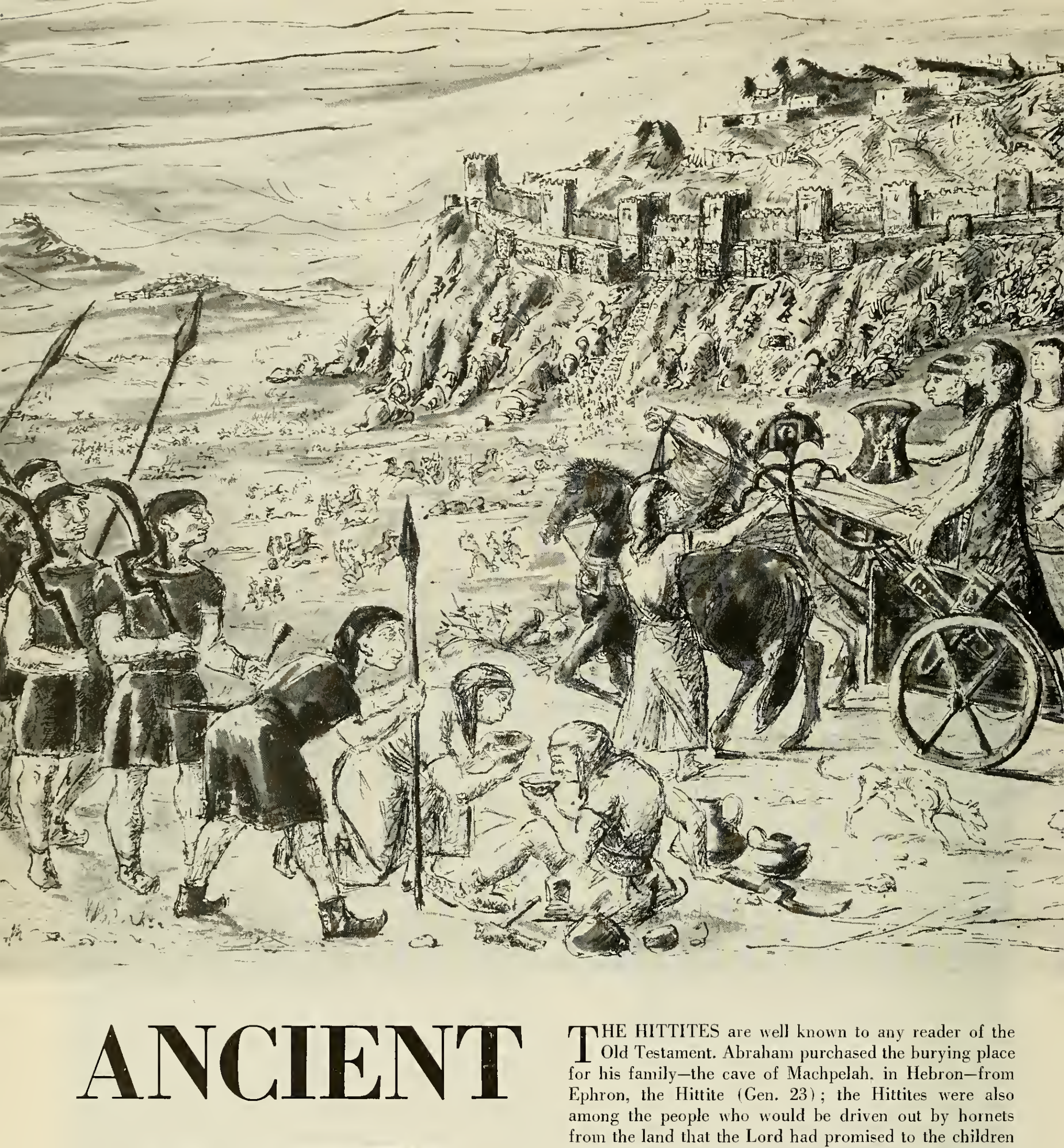
Three other fish have spawning habits that, in some respects at least, are similar to that of the grunion. One of these is *Hubbsiella sardina*, a closely related species which occurs in the upper part of the Gulf of California. Except for the fact that its spawning often takes place during the daylight hours, its reproductive habits are almost identical with those of the grunion. Observations by this author and reports from fishermen indicate that the *Hubbsiella* run on about the same dates as do the grunion. They also run at about the same time relative to high tide, though the times of high tides vary markedly between the two fishes' spawning areas. Many persons have observed the daylight spawning runs of *Hubbsiella*, since the beaches of Baja California can be easily reached from San Diego; but it is probable that night runs occur with more regularity than daytime runs. I myself have observed good night runs at Guaymas, Sonora, Mexico, in January, 1950. There were no daylight runs during the period studied.

A member of the true smelt family, the surf smelt *(Hypomesus pretiosus)*, which ranges northward from California, comes to the beaches to spawn, but does not actually leave the water to lay its eggs. The eggs are merely broadcast in the very shallow water of the wave wash; and unlike the grunion, there is no well-marked rhythm to its spawnings.

Finally, an Australian fish, *Galaxias attenuatus*, most closely approaches the grunion in its adjustment of spawning times to the moon phases—although it does not spawn on the beach. It seems to show about the same rhythm and regularity as does the grunion, even though its actual spawning habits are quite different.

DESPITE local concentrations during the spawning season, the grunion is not an abundant fish. Definite signs of depletion in numbers were evident as early as 1926. In that year, a closed season was put into effect, protecting these fish during April, May, and June. This legal protection, plus efforts to overcome pollution in southern California waters, appears to have been successful: good runs appeared once again, and by 1948 the population was judged large enough to allow for a longer open season, with June added to the list of open months. At present, there are no signs that this additional open month is causing any depletion, and it is probable that the grunion population can maintain itself at a high level under these rules.

AUTHOR AND SUBJECTS are shown here. To grunion students, as well as to grunion hunters, a flashlight is often useful; but it should be turned on only when waves have receded: if flashed on the water, light tends to frighten the fish away.

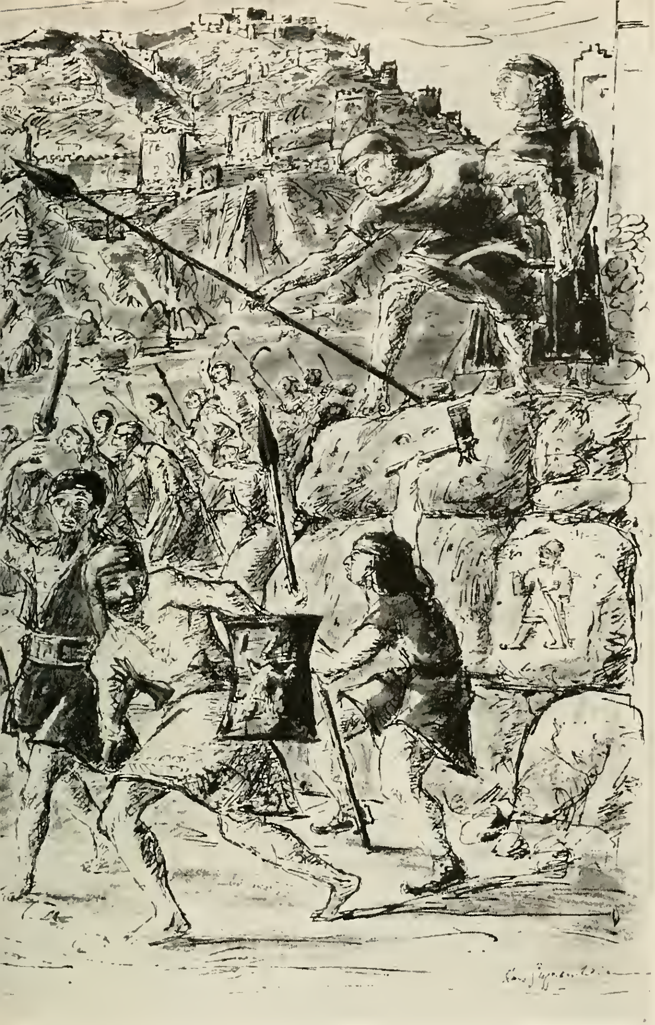


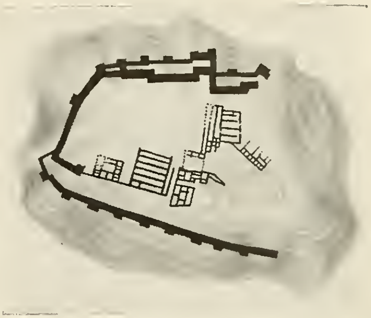
ANCIENT HATTI

The Hittites' way of life is now slowly being pieced together

By Edith Porada

THE HITTITES are well known to any reader of the Old Testament. Abraham purchased the burying place for his family—the cave of Machpelah, in Hebron—from Ephron, the Hittite (Gen. 23); the Hittites were also among the people who would be driven out by hornets from the land that the Lord had promised to the children of Israel (Exod. 23:28); and the memory of the Hittites was still alive in the time of the Babylonian Exile, when the prophet Ezekiel hurled at Jerusalem the abomination that her father was an Amorite, her mother a Hittite (Ezek. 16:3). The Hittites were therefore assumed to have been an important people in Canaan, in ancient times. When stones, covered with illegible, non-Egyptian hieroglyphs, were found in the northern Syrian town of Hama on the Orontes in the 1870's, they were soon called Hittite and associated with the victims of the Egyptian pharaohs, Seti I (ca. 1318-1298 B.C.) and Rameses II (ca. 1298-1232 B.C.), depicted in the reliefs of the Egyp-





Detailed layout of ancient Hittite city of Hattusha and its royal citadel, Büyükkale, has been re-created by work of archeologists.

Hittite warriors, armed with battle-axes, spears, and shields, fight outside the walls of Hattusha, defending their city by sorties down narrow staircase from one of the main gates. Sorties could also be made through underground tunnels built beneath ramparts.

tian temples of Luxor, Karnak, Thebes and Abu-Simbel.

Today we know that the hieroglyphic inscriptions of Hama and other northern Syrian excavations were carved at the order of princelings who ruled a mixed population, primarily Aramaean, between 900 and 700 B.C. and merely attempted to continue the glorious tradition of the Hittite Empire of earlier times. The circumstances that connect these later principalities, of the first millennium B.C., with the great Hittite Empire that flourished in Anatolia and northern Syria during the fourteenth and thirteenth centuries B.C. are only gradually being revealed. Equally recent is the evidence that draws the story of Abraham and the Hittite Ephron into the realm of probabilities. Not only has it been suggested that the actions of Ephron reflect Hittite legal concepts—in that he attempted to induce Abraham to buy the whole field, to rid himself of the feudal duties attached to that field, while Abraham for the same reasons tried hard to avoid buying more than the end of the field in which the cave was situated—but also the political importance of the Hittites in North Syria in the eighteenth century B.C. seems to have been considerably greater than was assumed by most scholars before the discoveries of the last few years.

Whether or not the age of the patriarchs can be correlated with the expansion of the Hittites into Syria depends on the dates assigned to both. Unlike recent European history, in which the years of Columbus' discoveries, for example, are unequivocally known, the days of Abraham vary—with different scholars' interpretations—anywhere from ca. 1900 to 1750 B.C. Likewise, the dates of the Hittites are not certainly fixed. A correlation is therefore still tenuous at best, even without considering the fact that no historical texts place the Hittites at any time as far south as Hebron. The nationality of Abraham's real estate opponent therefore remains speculative.

Hittite history has been divided by modern scholars into an "Old Kingdom," which probably began before 1800 B.C. and had its apogee in the seventeenth century B.C., and a "New Empire," in the fourteenth and thirteenth centuries B.C. Between these two major periods, fall two centuries of which very little is known. Until recently it was assumed that the Old Kingdom could not have been very extensive and that such campaigns as were conducted by Hittite kings into North Syria and even into Babylonia were merely unconnected raids (although the latter exploit was of major historical significance, since it put an end to the dynasty of the great Babylonian lawgiver, Hammurabi). Recent evidence, however, shows that these military campaigns were connected and caused a major break in the ruling dynasties (and the "old order") not only in Babylonia but also in Syria. The Hittite kings of the middle or end of the seventeenth century B.C. (depending on whether the Fall of Babylon is dated ca. 1650 or 1600 B.C.), therefore, seem to have been more important in the East than was previously believed.

That we are able to argue thus concerning events that lie three thousand years or more in the past is due in large part to the hospitality and generosity of the Turks, who, as the present inhabitants of Anatolia, have opened the peninsula's ancient sites to investigators. Scholars from abroad have thereby been able to share in the decipherment of the Hittites' written records, to the body of which new material is added with each season's excavations.

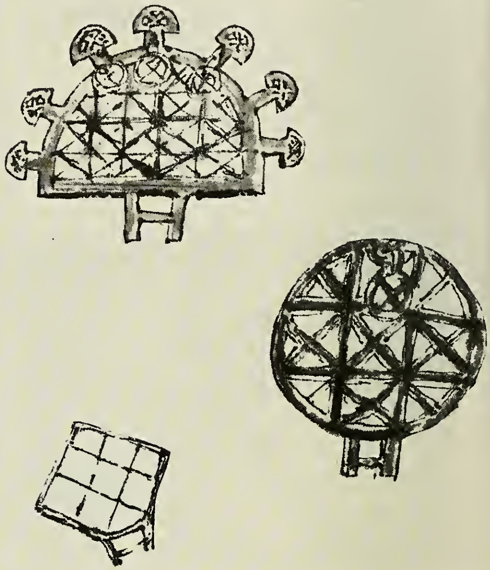
The largest number of these records was discovered in the ruins of the ancient city of Hattusha, which was the capital of the Hittites from the seventeenth to the thirteenth centuries B.C. This site—called Boghazköy today, after the modern Turkish village that lies at the foot of the ancient town—can be reached by car in four hours' drive over good roads from the Turkish capital city of Ankara. Here, at Hattusha, and at the nearby rock sanctuary of Yazilikaya, the German archeologist Kurt Bittel and his associates have continued since 1931 the excavations begun by Hugo Winckler in 1906, and are still pursuing their work under the sponsorship of the German Oriental Society and Archaeological Institute. Numerous volumes detailing this work have already appeared and yearly preliminary reports follow each season's efforts. The present article relies most heavily on Bittel's reports.

Among all the capitals of the ancient world, Hattusha—as it once was—can be most easily conjured up before the eye of the modern visitor. The ancient builders used a terrain so obviously suited to the creation of a fortified town that one can mentally reconstruct much of its original, gigantic layout merely by viewing the wide, fertile valley of the Budak Özü, where the ground rises in a triangle between two converging mountain ranges. Furthermore, the German excavators have so minutely examined the remains of walls and the traces of foundations cut into bedrock that they have been able to re-create on paper a detailed plan of much of the ancient town and its citadel. But most important of all are the texts discovered in Hattusha's royal and temple archives, which reveal to us the human beings who peopled these ancient structures—their fears and ambitions, their military achievements and reverses, their religious and legal practices.

The royal archives—which were discovered on the citadel, Büyükkale, which dominates the ancient city—consisted of several thousand clay tablets, varying in length from eight to twelve inches, rectangular in shape and slightly curved on the front. These tablets, placed on wooden shelves along the walls, were well catalogued for easy reference. Small, identifying, clay labels further facilitated the location of the texts.

The signs of the script were pressed with a small wooden stylus into the clay while it was still soft. Later, the clay dried and hardened and—if fired—became virtually indestructible. The marks of the stylus are wedge-shaped, or cuneiform—a legacy from Assyria and Babylonia, although it is not yet certain when this cuneiform script was actually taken over by the indigenous Anatolian population.

From the texts of the tablets, one fact has become clear: the very name, "Hittite," covers a multitude of languages of the heterogeneous peoples who spoke them. Not only are there tablets in the royal archives written in obviously foreign languages—such as Sumerian and Akkadian—but also in the Hattic language of the region's original population; in the Hurrian of northern Mesopotamia; in Palaic, an Indo-European language spoken in the far north of the Anatolian plateau; in Luwian, a language written with Hittite hieroglyphs; and finally, in the Indo-European language which we call "cuneiform Hittite" and which was called "Nesian" by the people themselves.



Pre-Hittite, Hattic cultural achievements were remarkably high, and are demonstrated by finds made in "Royal Tombs."

In part, at least, these different languages correspond to the different levels of population that archeological research has revealed to us. Hattic, for example, was surely the most important language in Asia Minor in the Early Bronze Age (and probably even earlier, in the Chalcolithic period). But, by the time of the Hittite Empire, the tablets

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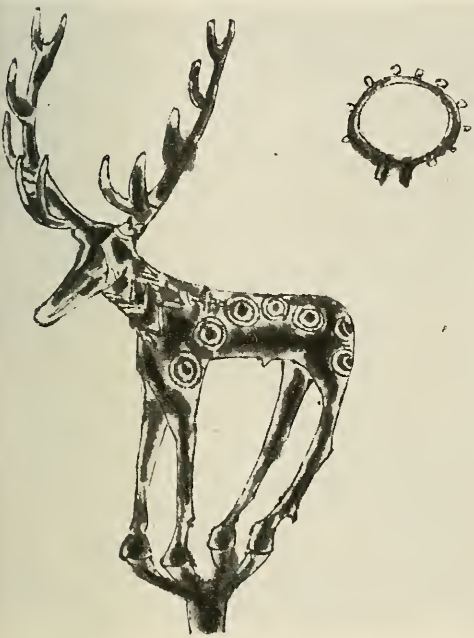
reveal that it was so little known that priests reciting ancient Hattic rituals had to have Hittite interlinear translations inserted in the texts.

Some scholars believe that the high material achievements of the pre-Hittite, Hattic culture are manifested in the finds made in the "Royal Tombs" of Alaça Hüyük, some fifteen miles north of Boghazköy. The most striking objects in these tombs, which are dated in the late third millennium B.C., are standards—in the shape of stylized stag or bull statuettes, made of copper and often including inlays and sheathing of silver and electrum. There are also variously elaborated copper disks and, in some cases, a combination of animal statuette with disk. These objects presumably had religious significance and it is interesting to note that stag and bull still played an important role in religious representations of the Hittite Empire, some thousand years after the time of the Alaça tombs.



Standards in the shape of animals and elaborate sun disks of copper or bronze are most striking objects in the tombs.

The uncertainty which surrounds the people who shaped Anatolian history in the third millennium B.C. is replaced, at the beginning of the second, by the records of the able Assyrian merchants who established trading posts in many Anatolian localities and had their largest colony outside the town of Kanesh, next to the modern Anatolian village of Kültepe. Suddenly, in their texts, we are faced with close-ups of businessmen of the nineteenth century B.C.: their dealings with each other, with the heads of firms back in the capital city of Assur and with the local Anatolian authorities. Most of the merchants' purchases consisted of copper, while the "home office" exports to Anatolia were largely tin and textiles.

The great merchants of Kanesh kept their records in their own archives, whence they have been brought to light by excavators during the past decade, together with the houses, pottery, seals and other objects used by the colonists. One might have thought that the colony would have made an attempt to re-create, in the beautifully situated site of Kanesh, much of their own home atmosphere but, curiously enough, most of the Assyrian excavated material is indistinguishable from contemporary Anatolian forms.

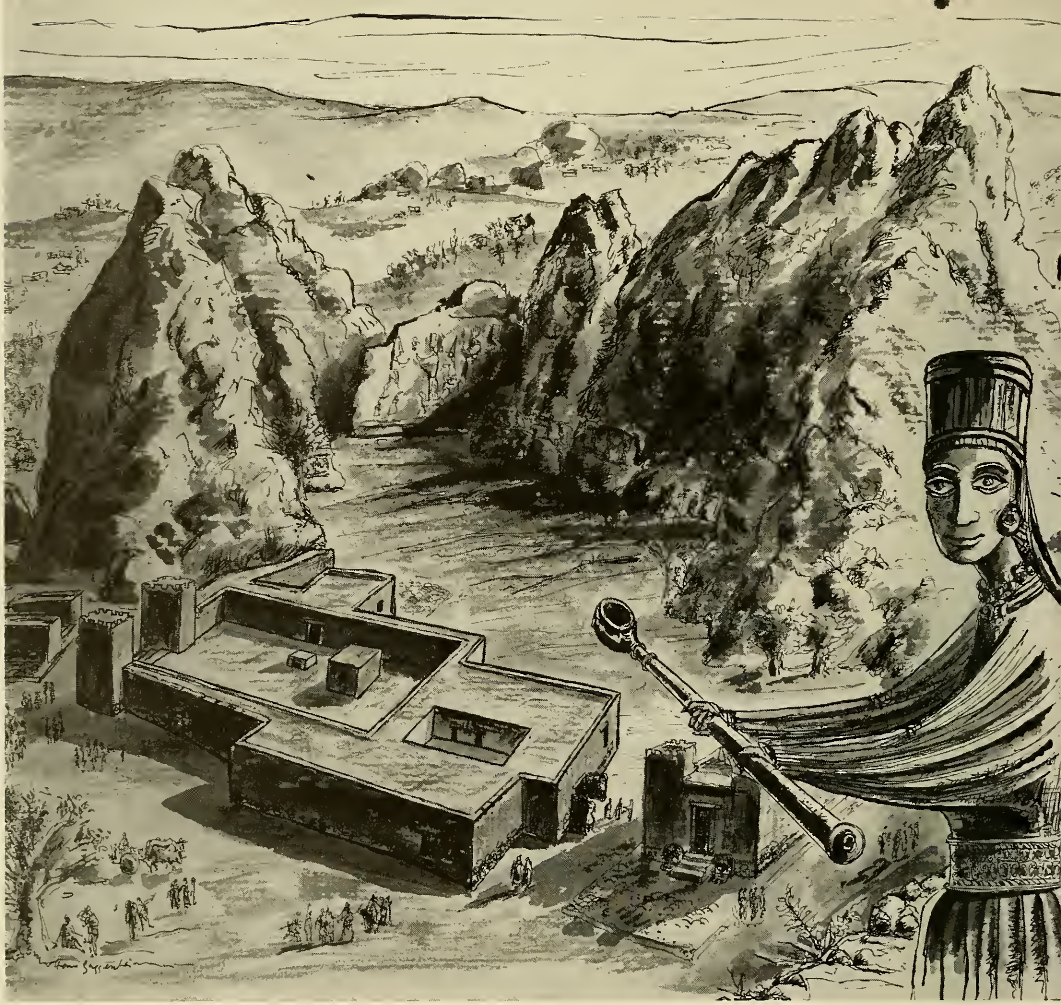
After three generations, the settlement at Kanesh was destroyed. A second occupation of the Assyrian colony in the early eighteenth century B.C. was smaller than the first. However, it was at this very time that an Assyrian merchant colony also came into being at Hattusha—in the lower town, just above the present village of Boghazköy.

The latter settlement, as well as the citadel, was destroyed in a terrible conflagration. This destruction may be related to the accounts of cities conquered by King Anitta of Kushar, predecessor of the Hittite Old Kingdom dynasty, whose text—although preserved only in a later copy—is nevertheless the oldest Hittite document now known. While Kushar, Anitta's residence, cannot be located as yet, we have known since 1954 that Anitta had an administrative building at Kanesh-Kültepe, since a dagger, or spearhead, was found there, bearing the inscription, "palace of Anitta the king." The dagger was not discovered in the settlement of the Assyrian traders mentioned before, but on the city mound where a palace or temple was excavated.

In his text, Anitta tells of the bitter resistance offered by Hattush (not Hattusha, as it was later called in Hittite times), and of the fact that he cursed it, never to rise again. Yet Anitta's successors, the later Hittite kings, completely disregarded his curse upon Hattush. They not only made the city their capital not more than a century or two later but also called their country Hatti. Perhaps it seemed natural to them to retain the name of the once most powerful element in the population, and to locate their capital both near the important trade route that connected the regions of the Black Sea with the Mediterranean coast, and in extraordinarily defensible terrain, which the Hittites, who were brilliant military engineers, were capable of exploiting for their fortifications.

The town of Hattusha extended upward along a gentle incline between two streams that had cut deeply into the mountain, isolating between them a pointed ridge with steep, rocky slopes. The convergence of these streams forms the Budak Özü, a tributary of the Delice Irmak, which, in turn, flows into the Kizil Irmak, the Halys of the Greeks.

In the area between the two streams extended the old town, crowned by the royal citadel on the highest point of the ridge. Much terracing must have been done on this hilly terrain to level the ground for building, and a view of the modern village of Boghazköy gives some idea of the position the ancient, vanished houses occupied on the rocky slopes. The construction of these ordinary dwellings probably did not differ much from modern Anatolian practice. Limestone and mud, and wooden beams for a flat roof, most likely served then, as now, for common building materials. However, the public buildings—such as the great temple in the lower city, called the Temple of the Weather God of Hatti by its excavators—had a socle of magnificent stone masonry for its superstructure of mud brick and wood.



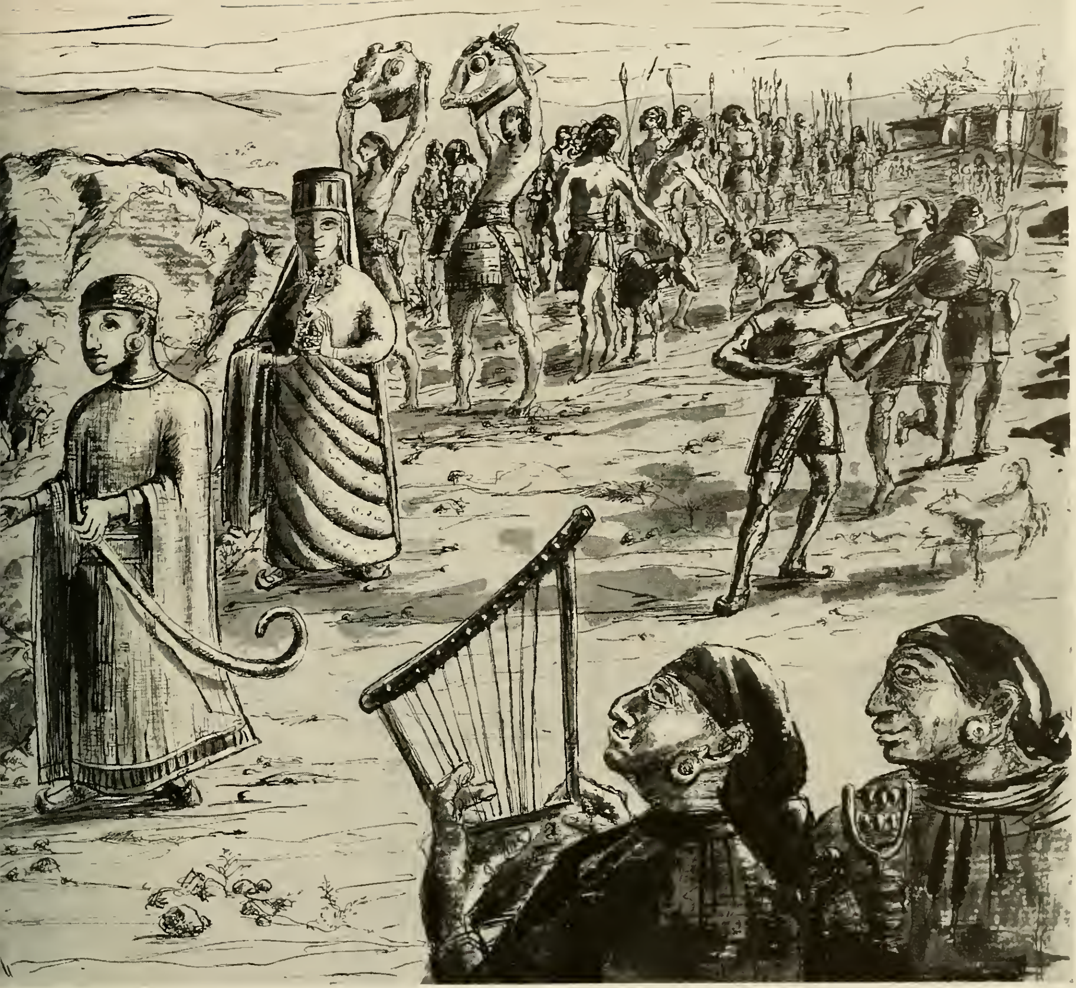
Religious procession, led by a priestess with a libation vessel, winds toward rock sanctuary at Yazilikaya. King is next, wearing cap and carrying a sword. The Queen follows,

The largest of the building blocks used in the temple weighs some thirty-six tons and its transportation must have been an extraordinary feat. Such tremendous boulders were probably moved on a sledgelike conveyance, which, as shown by an Assyrian relief of the seventh century B.C., was pulled by long columns of men. The lesser blocks, however, were probably brought to the site on the kind of two-wheeled carts, drawn by oxen or water buffaloes, which continue to be the most common vehicle for the transportation of heavy loads in the Anatolia of today.

Some time after 1600 B.C., the entire city of Hattusha was surrounded by a fortified circuit, some four miles in length, consisting of a high main wall and a lower outer wall. While the latter had a massive ashlar socle, the main wall was built according to the Hittite "box" system—in which separate outer and inner walls were connected by cross-walls and the resulting "boxes" filled with a rubble of earth and stones. This construction provided a solid foundation for the superstructure of battlements and parapet (which is nowhere preserved today, but which probably consisted of mud brick with a wooden framework).

Along the main wall, at fairly regular intervals of seventy-five feet or so, stood towers that projected beyond the face of the wall to a distance of fourteen to twenty feet. Although only the foundations of these towers have been preserved, we may assume them to have been fairly high, since they allowed the defenders of Hattusha to overlook the terrain beyond both wall systems.

The southernmost point of the wall system around Hattusha—at the so-called "Yerkapu"—was particularly strongly fortified. In this location, there was no natural protection for the town, since the site rises up to the mountain behind it. Here, the tremendous size of Hittite planning becomes most evident: a deep cut was made through the mountain shoulder, to sever it from the town site. The earth fill gained thereby was used to form a high rampart, paved with great stone slabs, and a gate, decorated with sphinxes,



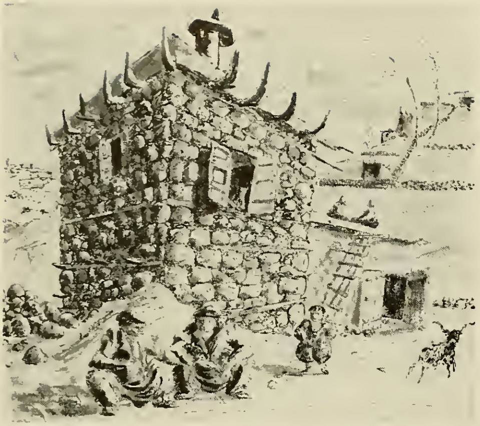
holding a small god. Other celebrants hold up silver animal heads, as musicians play flutes, strings, and drums. At left, is artist's reconstruction of the temple in the sanctuary.

led through a mighty tower into the open space between the outer and main walls. From this gate, and from gates in the outer wall, the defenders could rush down the rampart by way of two narrow and rather steep sets of steps, meeting the enemy in the area outside the walls. To judge from Homer's account of the Trojan War, it was in this area that most of the fighting over fortified sites in Asia Minor seems to have taken place.

In addition, an underground tunnel, or postern, over seventy-five yards long, was built under the walls and the rampart at this point. The postern could also be used for sorties and could be easily defended by a few people. This tunnel can still be traversed for its entire length, and even the watchman's seat at its exit has been preserved.

If an enemy, despite these defenses, nonetheless forced an entry to the city, resistance could still be offered. Entire quarters within the town could be sealed off by transverse walls and defended by the small fortresses erected on the rocky plateaus that rise from the earth within Hattusha's bounds. The largest, though not the highest, of these bare rocks is Büyükkale, the royal citadel.

ADDED to its natural defensibility, Büyükkale has the most carefully constructed and grandiose fortifications. Its northern and eastern slopes are almost unscalable cliffs, and this natural advantage was almost equaled on its western and southern slopes by a facing of stone slabs. The ascent to the citadel leads up the western slope, under the protection of an upper and lower wall, to a monumental gate in the southwest corner of the plateau. Another means of entrance to the citadel is provided by one of the underground posterns favored by the Hittites, the tunnel's entrance lying in back of the eastern gate tower, and its exit at the foot of the citadel hill. Two large cisterns for water were hollowed out in the northwest corner of the citadel. From there, the water was distributed by pipelines to the different rooms of the royal buildings, of which only



Modern peasants' house in Turkey is constructed in much the same manner as ancient Hittite dwellings. Wooden fence around the roof helps store snow, which is used for water.

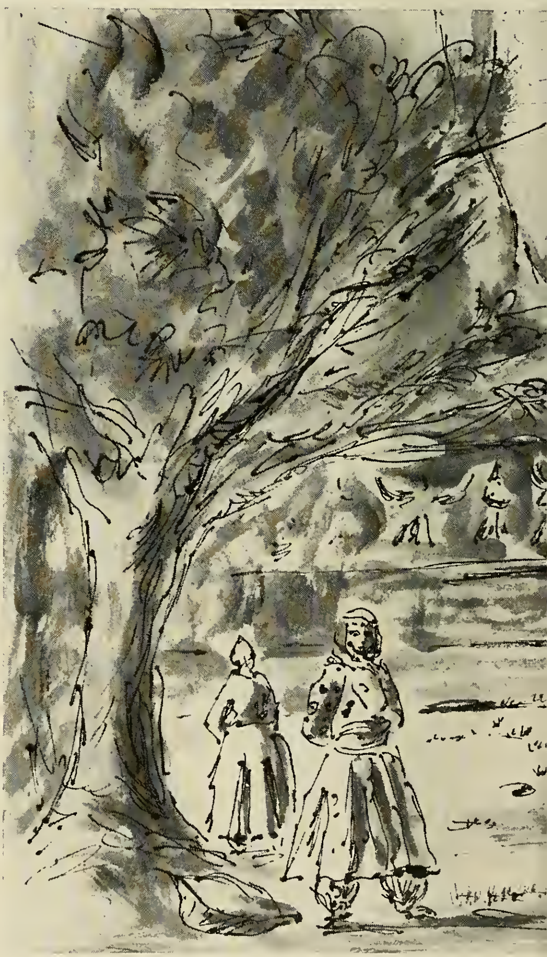
the foundations and substructures are preserved today. The largest of these, with a length of about fifty yards and a central position in the front wall of the citadel, must have been visible from the town below. This building was probably the royal audience hall. Other foundations may be identified with some probability as archives, and one as the base of a cultic building.

So much for the bare stones. What of the life of Hattusha? Between the Old Empire and the New, historical documents cease for two hundred years. This is a period which is equally undocumented in upper Mesopotamia and northern Syria, a fact which may be due to the expansion of the Hurrians—a people whose language has been compared to Basque and to some of the languages of the Caucasus. Leaders of one group of Hurrians were what seems to have been a small group of Indo-European chariot warriors, called Mitannians. During the dark centuries in which Mitannian power appears to have been dominant, much Hurrian influence penetrated Hittite culture, probably even cuneiform writing—which the Hurrians had adopted in the course of their century-long contact with the Mesopotamian peoples.

Records set in again about 1430 B.C., at the beginning of the New Empire—which reached its greatest extension under King Shuppiluliuma (ca. 1385-1345 B.C.). Before his ascent to the throne, the Hittite nation had been hard pressed, with at least seven different groups of enemies threatening from all sides. Most dangerous for Hattusha were some northern tribes which once even burnt and pillaged the capital. To avoid repetition of such a disaster, the defensive circuit of Hattusha, just described, may have been built in the time of the great Shuppiluliuma.

We are afforded an extraordinary insight into the life of a royal family of the fourteenth century B.C. by the survival of accusations of Shuppiluliuma's son, Murshili, against his stepmother, Shuppiluliuma's widow. Murshili presents the dowager queen as the proverbial wicked stepmother, accusing her of having caused his own wife's death by a curse, of having caused him a speech impediment, of having solicited and received money from improper sources and of having introduced reprehensible foreign customs.

The old queen was a Babylonian (Kassite) princess. Probably it was not difficult to arouse suspicions and ill will against a foreigner at the Hittite court, although marriages with foreign princesses were, of course, an accepted tool of ancient diplomacy. In fact, no less an Egyptian queen than the widow of Tutankhamen tried desperately to obtain a Hittite prince as a second husband. Again, the archives present a fascinating and detailed story. Not having had an answer from Shuppiluliuma to her first request, the Egyptian queen sent envoys a few months later, from whose interview with the suspicious Hittite we quote



Two Turkish women stand under a tree at the entrance to the rock sanctuary at Yazilikaya. Here the walls were first cut back, then a seemingly endless procession of gods and

Dr. Porada, a member of Columbia University's Department of Fine Arts and Archeology, has written several books on the ancient, engraved seal stones of the Near East.

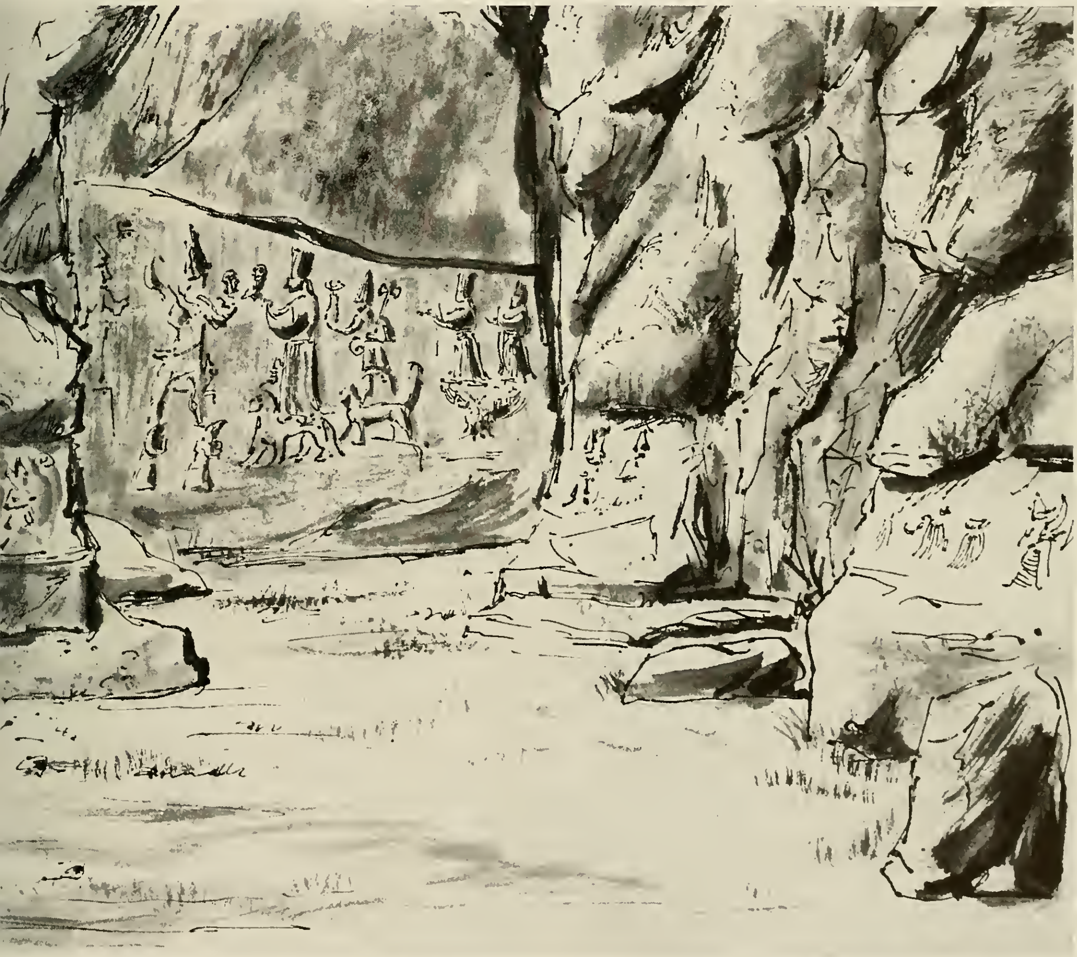
the following (in the translation of H. G. Güterbock):

"You keep asking me for a son of mine (as if it were my duty). He will in some way become a hostage, but (king) you will not make him." The Egyptian envoy replies:

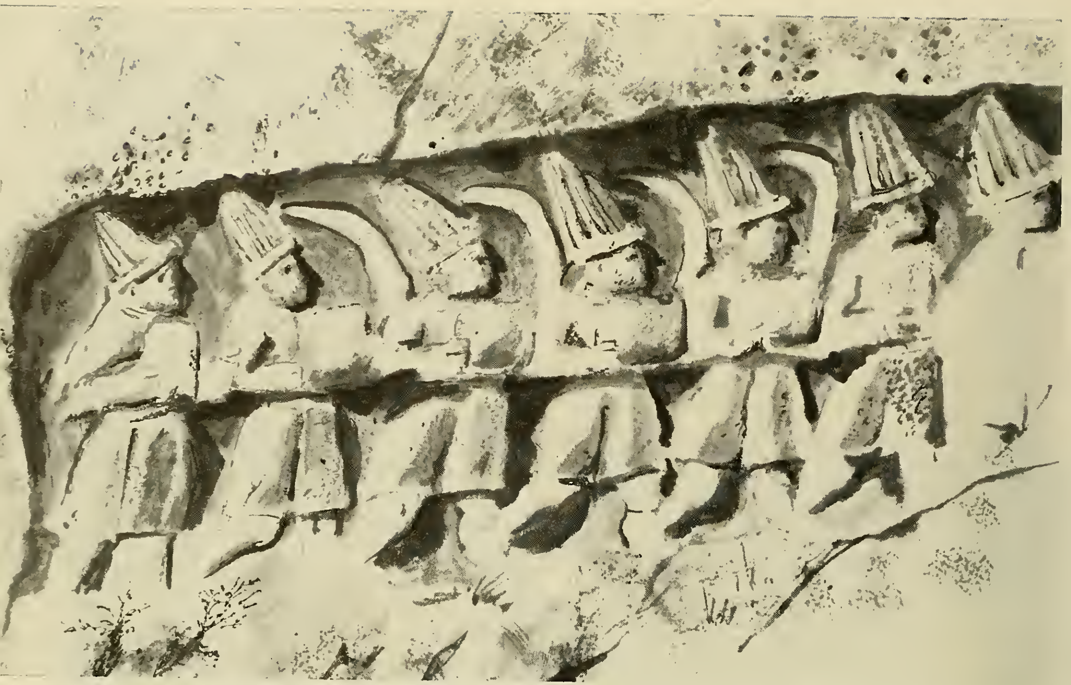
"Nibhurya (Tutankhamen) who was our lord, died; a son he has not. Our lord's wife is solitary. We are seeking a son of (Shuppiluliuma) for the kingship in Egypt, and for the woman, our lady, we seek him as her husband! Furthermore, we went to no other country, only here did we come."

During the following century, the Hittites and the Egyptians were the two greatest powers in the Near East. The inevitable clash over which empire would predominate in Syria and Lebanon was fought between Muwatalli and Rameses II at the battle of Qadesh, in the hill country of the upper Orontes River (ca. 1294 B.C.). The outstanding events in this battle were a ruse of the Hittites, by which the Egyptian king and part of his armed forces were lured into a dangerous position; a great Hittite attack on Rameses' camp; and the extraordinary Egyptian breakthrough to the river. Undisciplined Hittite plundering of the captured camp enabled Rameses to call reinforcements, with which he was able to break through the Hittite lines, although he did not take Qadesh and the battle was never the great victory it is represented to be in Egyptian reliefs. Indeed, it was followed by a treaty between the second successor of Muwatalli and Rameses II, concluding peace and recognizing Hittite domination of northern Syria.

As long as the Hittite Empire survived, religious life played a predominant role. The great temples had parks, fields, and herds; textiles, treasures of metal and provisions were heaped up in their storerooms. The number of priests attached to one of these sanctuaries must have been large; in addition, there were craftsmen and

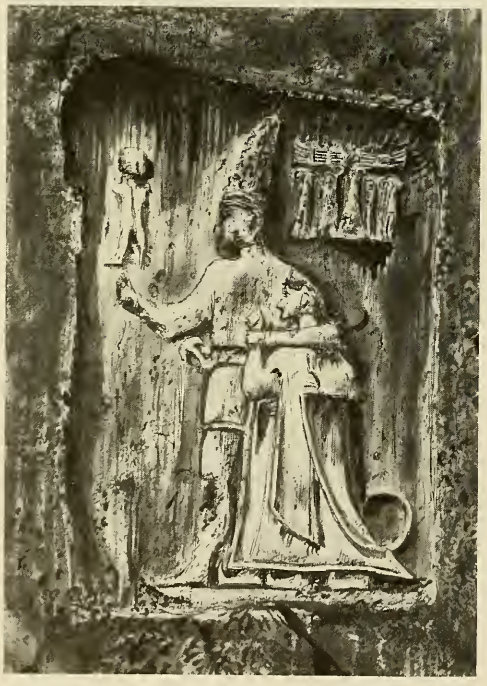


goddesses engraved in the rock. Teshub, the Weather God, heads the male deities. He is greeted by Hebat, leader of the female deities, who is riding on a panther. Other gods and goddesses follow Hebat and Teshub, and hieroglyphics explain the scene. Yazilikaya is the modern Turkish word for "inscribed rock." Sanctuary faces the former temple site.



Warrior gods with scimitars, *above*, form the reliefs in a smaller sanctuary branching from the first. King Tudhaliya (ca.1260-1240 B.C.) is shown in the embrace of a god, *below*.

Twelve-foot relief, *right*, was found in southeastern Anatolia and probably dates to about the 8th century B.C. This huge figure is now in the museum at Ankara, Turkey.

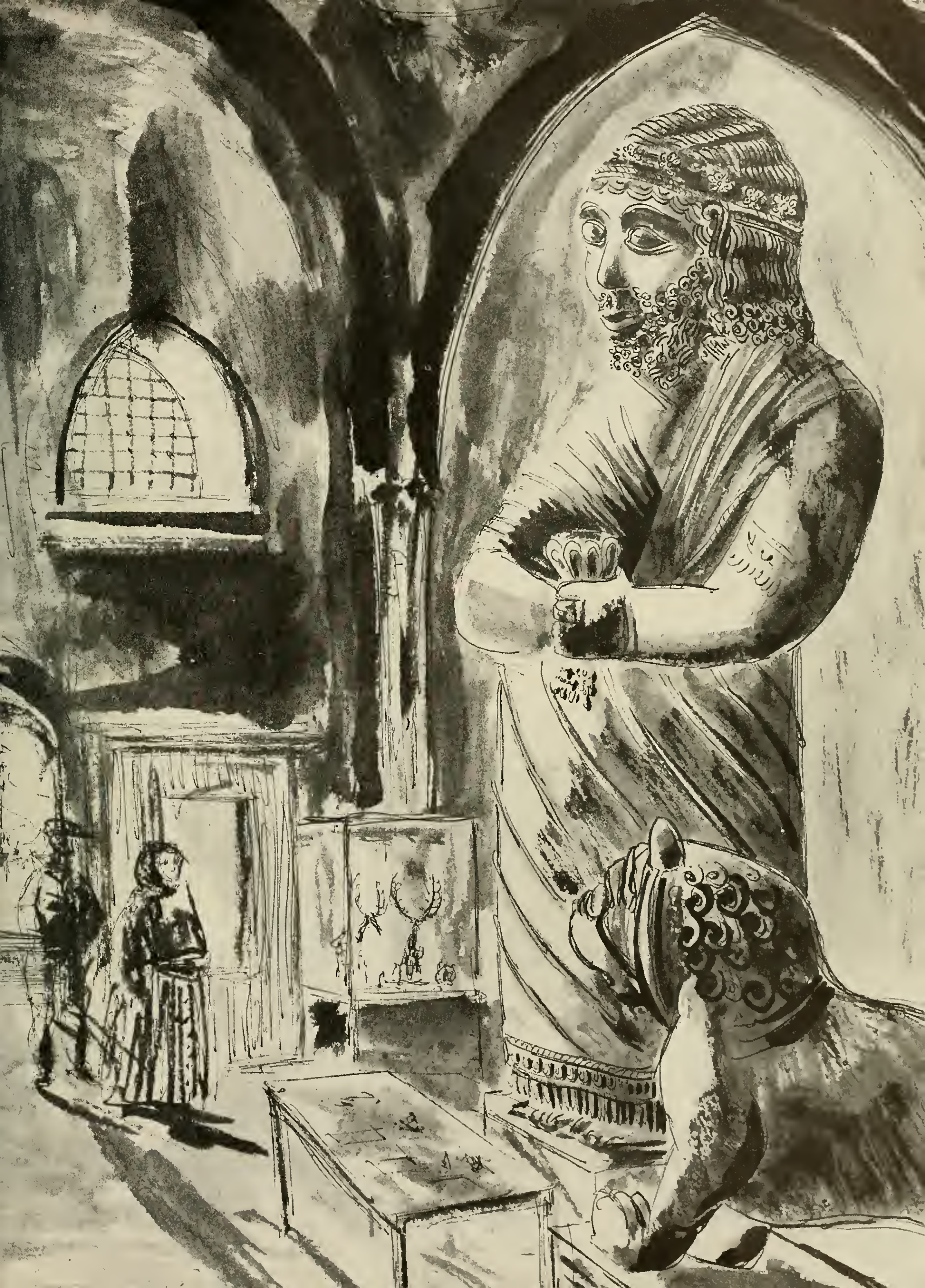


workers for the maintenance of the buildings, and singers who performed in the rituals. Supervision over all aspects of the work was exercised by the king.

There were daily sacrifices to the gods according to carefully prescribed rules, in which cleanliness played a considerable role. On special days, however, the king—in his function as high priest—performed the sacrifice himself. The following account of such a ritual has been reconstructed from several Hittite texts by Albrecht Goetze of Yale University, dean of Hittitologists, from whose writings much of the historical and literary information in this account has been derived.

The usual royal festival begins in the morning with the opening of a building (possibly called House of Rest) in which the king appears to have slept. The king first goes to a washhouse for his ablutions and the donning of his robes. The procession to the temple starts at the House of Rest, and passes through the gate into the temple court, where further cleansing ceremonies take place. Then the king enters the temple, where he throws himself to the ground and, after additional rites, assumes his seat on the throne. His insignia of office are brought in and set in place.

The main part of the festivity consists in a ritual repast. While the dignitaries are assigned their places, the king breaks a loaf of bread with a lance, after which the assembled group receives bread and drink. The king unveils the table placed before him by pulling away the covering cloth, which he throws among the retinue. The meal is terminated



by sweeping the room. Just such ceremonies as this must have been seen in the above-mentioned temple of the Weather God of Hatti. In an annex at the back of the temple building, in the middle of the rear wall, a square cavity remains—probably the emplacement for the statue of the principal deity. Some idea of the appearance of this statue (of which no trace remains) may be formed from the reliefs of deities at Yazilikaya (the name is modern Turkish for "inscribed rock"). This rock sanctuary is situated in the hills over a mile away from Hattusha, from whence processions must have been made on festive occasions.

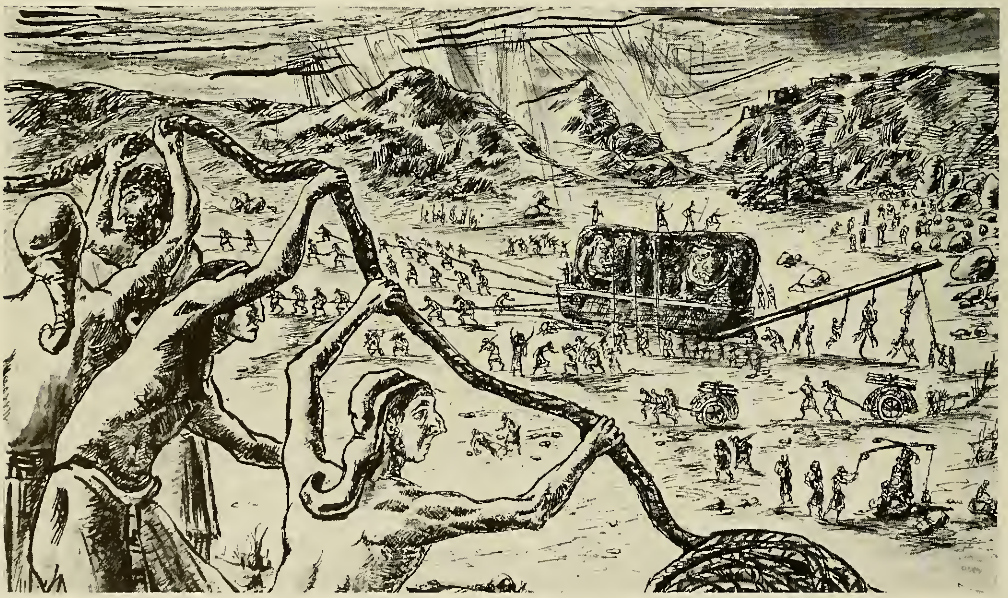
In the first chamber opposite the entrance to the sanctuary, there is a seemingly endless procession of gods. In the center, the largest goddess is represented, astride a panther or lion that is standing on mountains. The goddess wears a robe girded at the waist and a tall, cylindrical headgear, marked by vertical ridges and crenelations—a mural crown. Over her extended hand, which forms a fist with the thumb pointing forward, appear hieroglyphs denoting her Hurrian name, Hebat: her other hand is raised, perhaps in a gesture of greeting toward the god who faces her. The latter wears a short-sleeved garment reaching above the knees, his waist is circled by a broad belt into which a dagger is stuck. He carries a mace and extends his hand under the hieroglyphs that identify him with the Weather God Teshub, the chief deity of the Hurrian pantheon. His feet rest on the necks of two smaller mountain gods whose heads are bowed.

Between these two great deities appear the foreparts of two divine bulls. Behind the goddess Hebat comes her son, also standing on a panther or lion; then there are two goddesses, on a double-headed eagle, in the same posture as Hebat. Other female deities follow behind them, while male gods form a similar procession behind their leader Teshub.

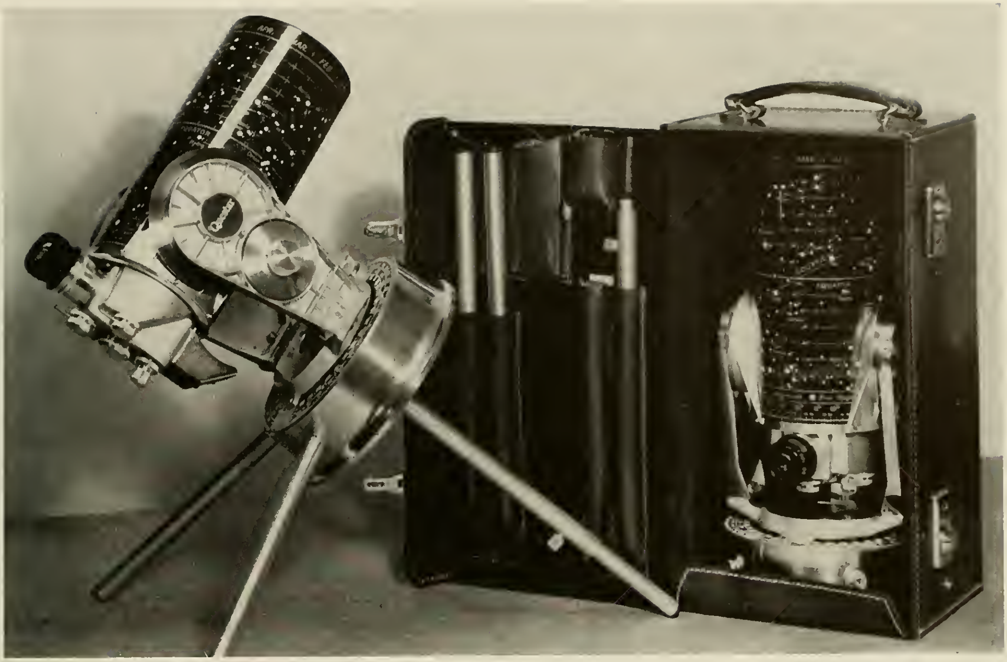
The entrance from the large to the small chamber at Yazilikaya is guarded against intruders by two lion-headed demons. In the small chamber, the reliefs are much better preserved, especially a row of twelve running warriors, armed with scimitars—presumably a detachment of militant gods. Perhaps the most expressive of these reliefs is one showing a king—recognizable by his tight-fitting cap, heavy mantle and curved staff, or lituus—in the gentle and protective embrace of a tall god. The trust which the Hittite put in their deities could not be more tellingly portrayed. The hieroglyphs of this king are read Tudhaliya—identified by many scholars with the fourth ruler of that name (ca. 1260-1240 B.C.). The reliefs in the main chamber, where the gods bear Hurrian names, are ascribed to the influence of Tudhaliya's mother, a princess from the strongly Hurrian region of southeastern Anatolia.

Shortly after the reign of Tudhaliya IV, the great Hittite Empire was submerged in the invasion of barbarian tribes which moved into the eastern Mediterranean regions. Hittite refugees appear to have sought new homes in northern Syria (which the Assyrian kings of the ninth and eight centuries B.C. still called Hatti and whose numerous princelings are also mentioned in the Old Testament).

Names recalling those of the great Hittite Empire were borne by many of these rulers, who commissioned hieroglyphic inscriptions such as those, from Hama, mentioned at the beginning of this article. The gulf which separates these "Neo-Hittite" kingdoms of Syria from the great Hittite Empire, however, is best illustrated by the difference which exists between the stiff and stocky figures of these later. Neo-Hittite works and the tall and elegant gods and kings who freely stride over the rocks of Yazilikaya.



Stone blocks, some weighing as much as 36 tons, probably were moved by sledges with ropes attached. Tablets tell of the king and his court watching such operations as this, in which sculpture for a temple is being moved from a quarry.



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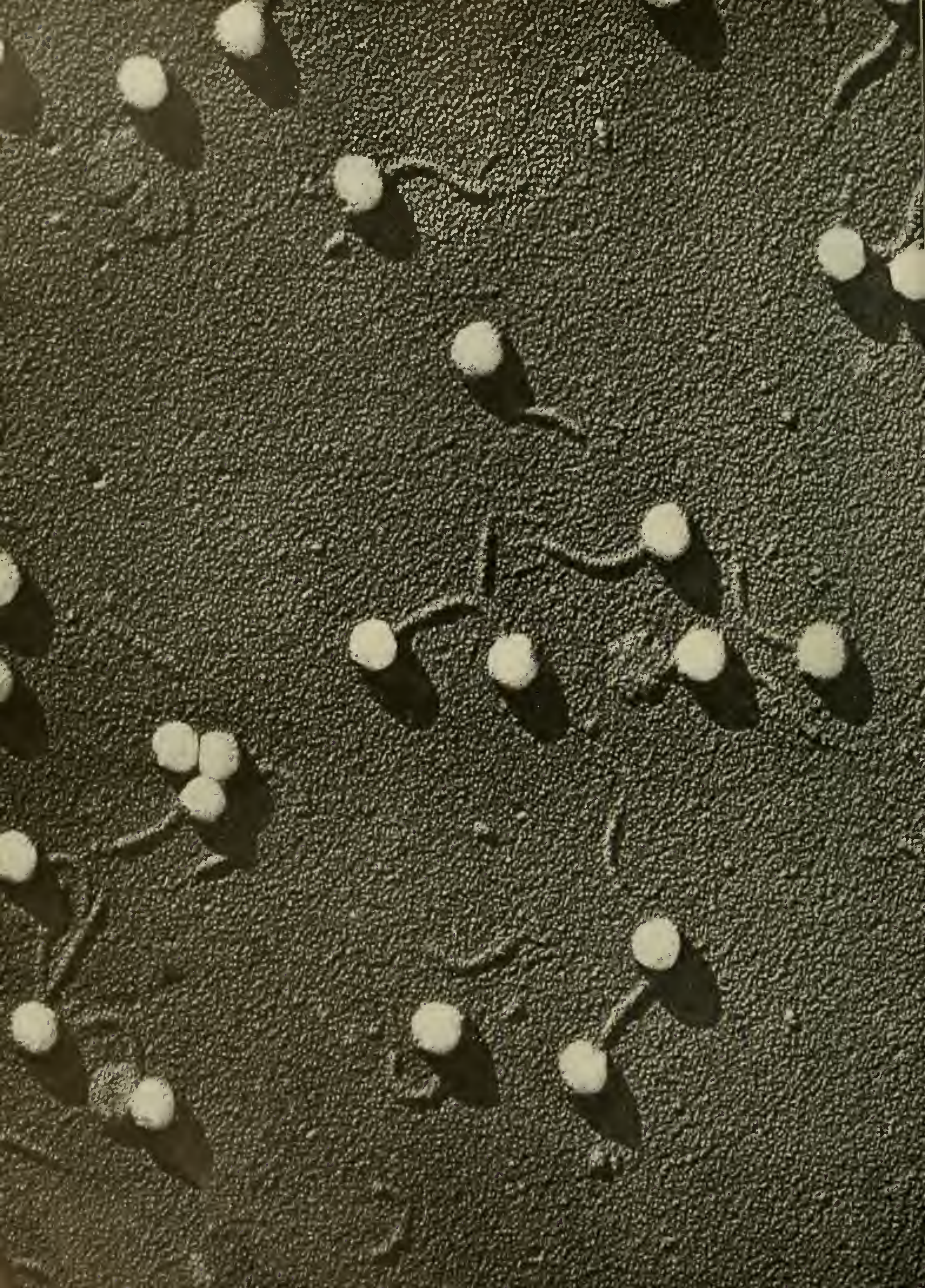
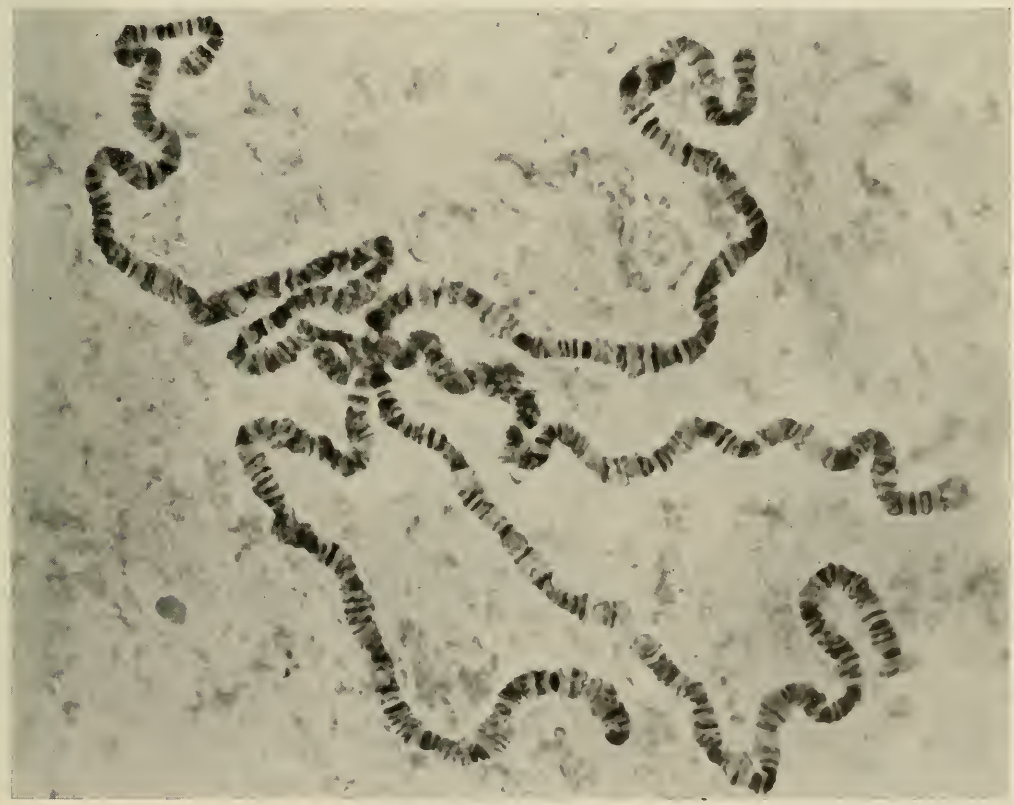


THE CAMERA AS A RESEARCH TOOL

IN his efforts to understand complex phenomena, the scientist must first isolate and examine single aspects of the natural world. Only as these are understood can their relation to one another, and to the whole of which they are a part, be clearly grasped. In this task, the human eye and even the microscope and telescope—which are only devices to extend the power of sight—are often far less useful than the camera. For one thing, the camera provides a record for study that even the most perfect visual memory could not reproduce—the phenomena are both too complex and too fleeting. Then, too, the camera is essential in recording events that occur very rarely—because they are either simply infrequent in nature or expensive to reproduce in the laboratory. Finally, some phenomena cannot be transmitted by the light rays of the visible spectrum, and other wave lengths must be used instead. Whatever the case, the results of this research through photography can be startlingly beautiful—as the pictures on these pages show. They are taken from a portfolio called *Scientists' Choice*, selected by specialists in several fields, edited by Franklin M. Branley of the staff of THE AMERICAN MUSEUM-HAYDEN PLANETARIUM, and published by Basic Books.

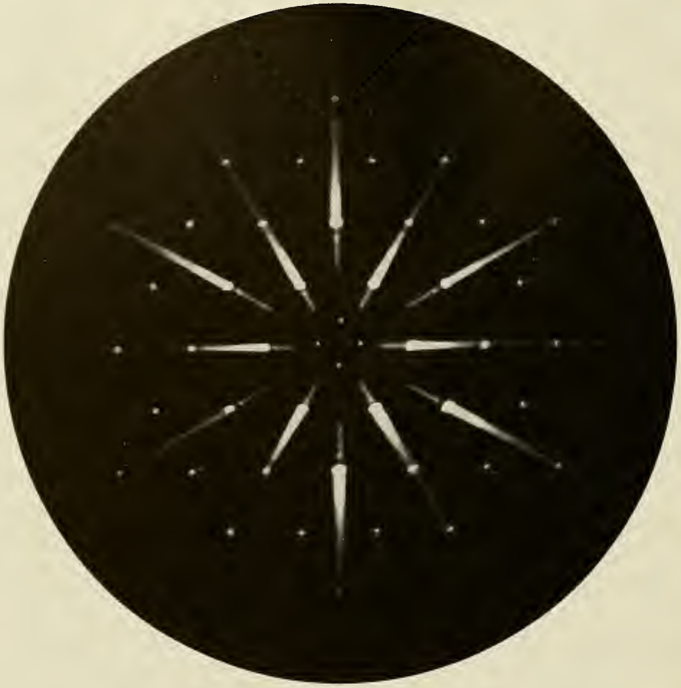


BACTERIOPHAGES

The viruses seen at left are called bacteriophages because they destroy bacteria (from Greek *phagein*, to eat), to which they attach themselves with their tails. They are seen here through an electron microscope, magnified 500,000 times.

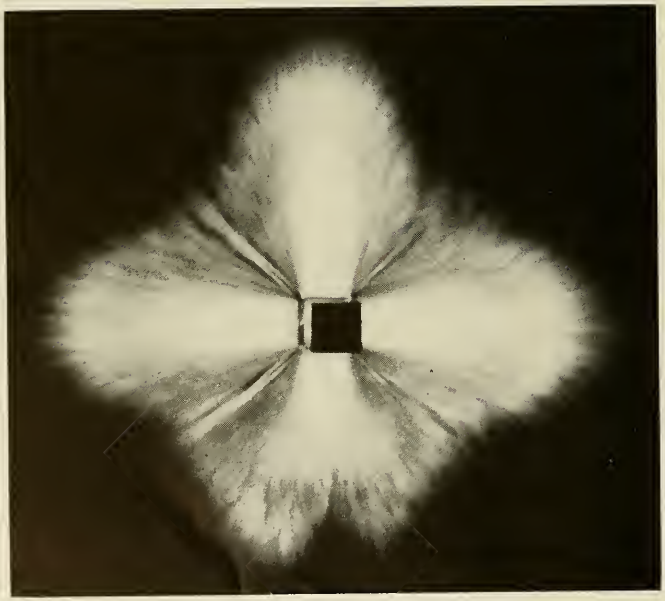
CHROMOSOMES

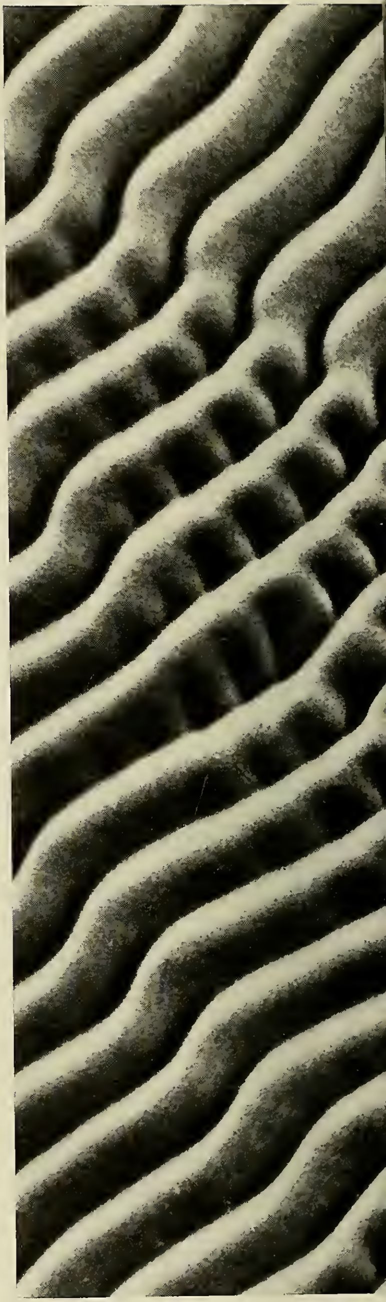
The fruit fly, *Drosophila melanogaster*, is very often used in genetics experiments because of its short life and great fertility. In the once-in-a-million photo above, the genes composing the chromosomes appear clearly as separate bands.



SINGLE ICE CRYSTAL

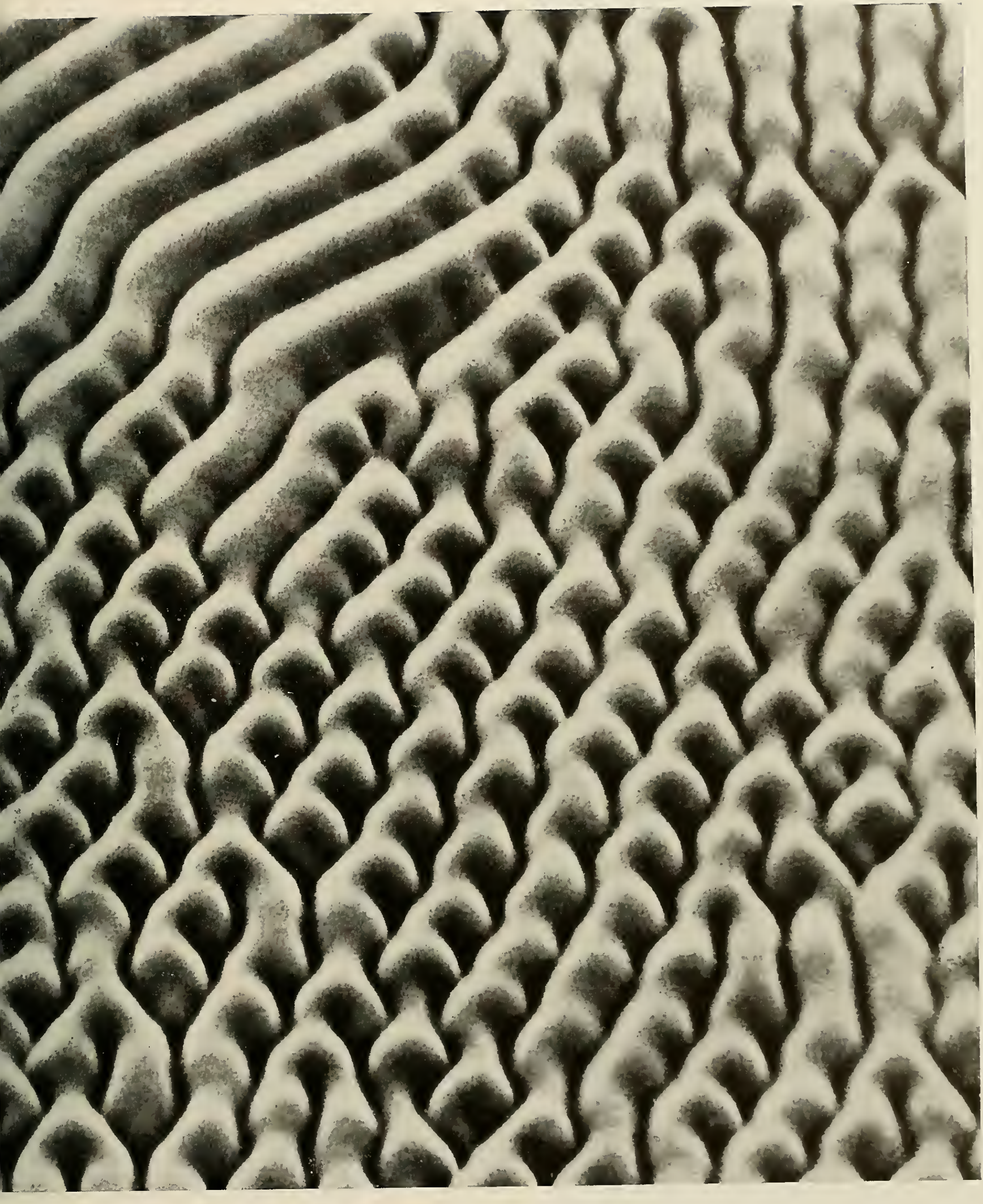
The symmetry of this ice crystal was photographed on X-ray film in a one-hour exposure. In taking the picture, many attempts with distilled, double-distilled, and even triple-distilled water all yielded twinned crystals; and only when, after ninety hours of failure, impure water was used did this single ice crystal result.





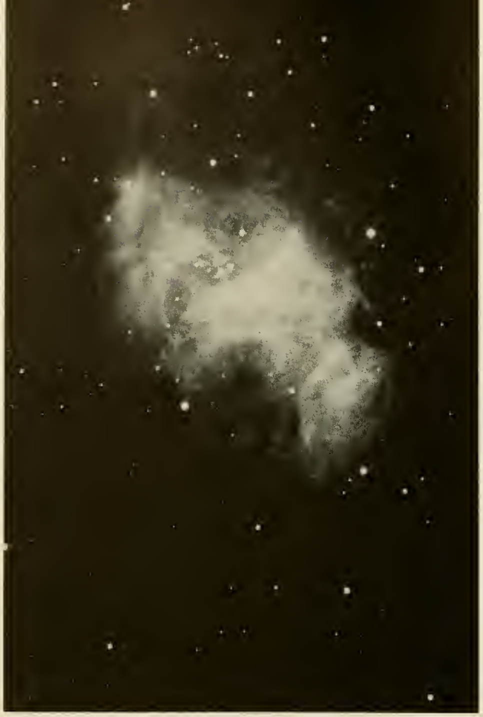
PENTOLITE

The photo, *left*, is not of a flower, but of the substance pentolite exploding. It was made about 15 microseconds after detonation. Exposure: 1 microsecond.



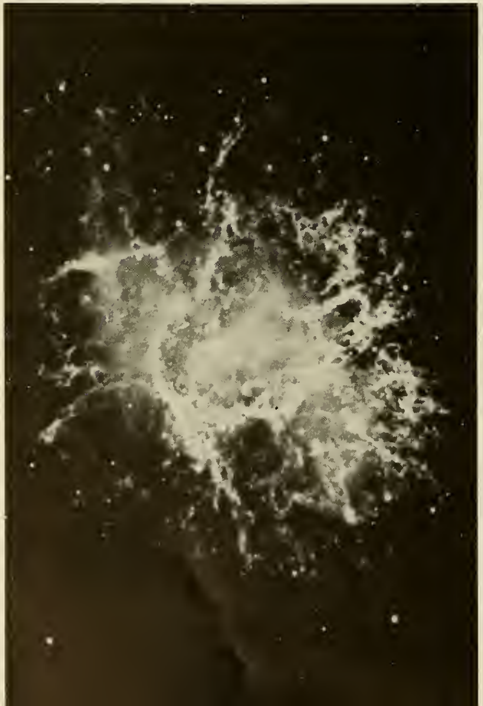
GAS FLAME'S SURFACE

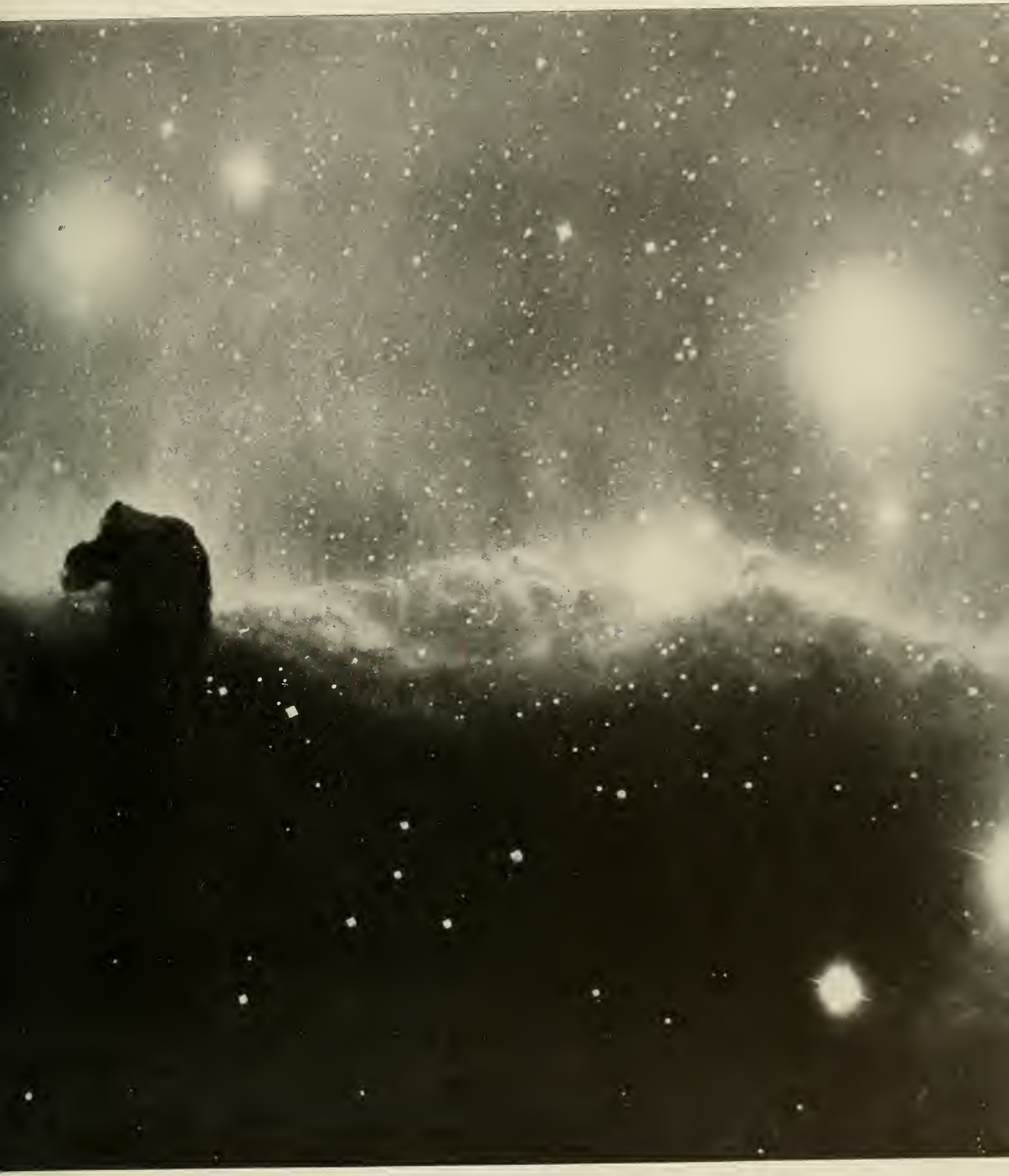
Normally, a gas flame includes three components: a stream of unburned gas; a narrow, smooth surface of flame; and an emerging stream of burned gas. But the interaction of these components can cause a peculiar instability, and then the flame surface is not smooth, but shows cell-like wrinkles. To study these cells, the film for this picture was moved from bottom to top during exposure. Thus, the slope of the dark traces gives information about the speed of the cells.



THE CRAB NEBULA

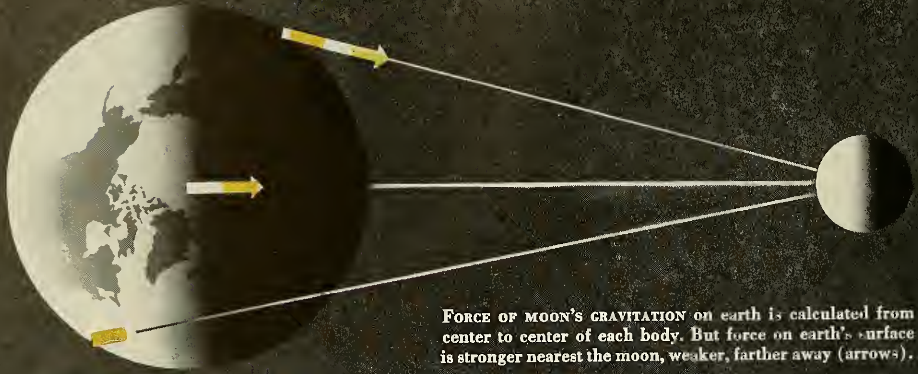
Two pictures of the same object show importance of photo techniques in modern astronomy. Smooth outline, *above*, was recorded by plate sensitive to light just beyond visible red; *below*, crimson light shows complex hydrogen structure.



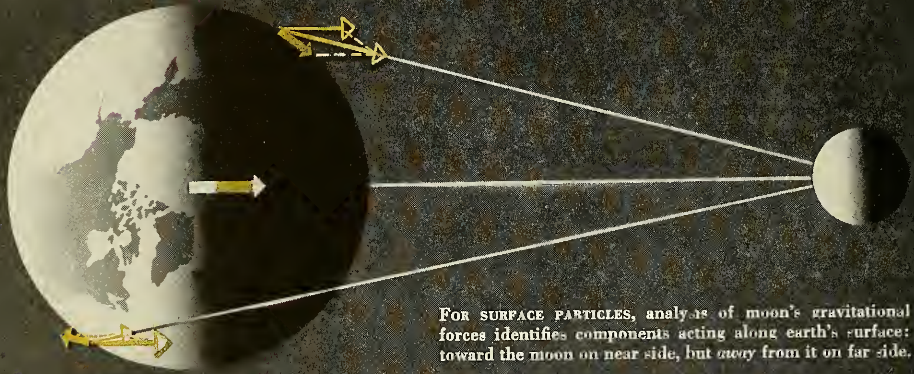


THE HORSEHEAD NEBULA

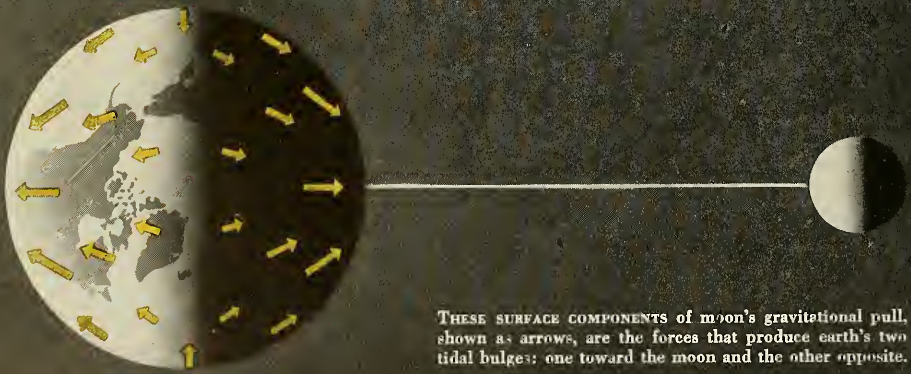
This configuration, so named because of the shape seen at its center, is made of a vast cloud of dust and gas. Such clouds, called nebulae, are found in the interstellar spaces, and though their density is almost unimaginably low, their size enables them to be seen with modern instruments. The presence of nearby stars illumines them, as with the Crab nebula shown at left. If no stars are nearby and the cloud's density is relatively high, the darkness shown here results.



Force of moon's gravitation on earth is calculated from center to center of each body. But force on earth's surface is stronger nearest the moon, weaker, farther away (arrows).



For surface particles, analysis of moon's gravitational forces identifies components acting along earth's surface: toward the moon on near side, but *away* from it on far side.



These surface components of moon's gravitational pull, shown as arrows, are the forces that produce earth's two tidal bulges: one toward the moon and the other opposite.

PART I

THE TIDES

One of mankind's earliest scientific observations linked the moon with the tides, but the relationship is far from simple

By THOMAS D. NICHOLSON

A GOOD MANY YEARS AGO, during my seafaring days, I had occasion to check the tide tables for the Society Islands in the Pacific. We were headed for Bora-Bora, near Tahiti, and I was Cadet aboard a troop transport en route to the Far East, early in World War II. My watch officer had assigned me to check the stage of the tide before we made our entrance into the lagoon.

I was surprised to learn that in contrast to the rest of the world, where the tides are governed principally by the moon, the tides at Tahiti—and in the whole Society Group—are predominantly solar tides. The Coast and Geodetic Survey *Tide Tables* footnoted the information: "Except near times of the moon's quadrature, when the range of tide is negligible, the high waters usually occur about noon and midnight and the low waters about 6 A.M. and 6 P.M."

Now, ignoring "quadrature" for the present, this is indeed strange to anyone who knows the tides. One of the most obvious facts is that high tides—or low tides, for that matter—do not occur at the same time every day. Day by day, they come an average of fifty minutes later. Thus, the tidal "day" is about twenty-four hours and fifty minutes long—the same length of time as our own day would be if it were measured by the motion of the moon across the sky. This fact has been known for thousands of years: indeed, it was the first clue to the association of the moon with the tides, although the nature of that association has come to be understood only in recent centuries.

Along the shores of the world, the tides follow a generally consistent pattern; two high tides and two low tides occur each day. The two high tides come about twelve hours and twenty-five minutes apart, while the low tides fall between. The time of high tide, anywhere in the world, follows the time the moon passes over the meridian of that particular place (or over the matching meridian on the *opposite* side of the earth) by an interval that shows remarkably little variation (illustrations, pp. 328-29, top).

BUT the Society Islands seem to be excused from this general tidal "law." Many years after I first became aware of this Pacific tidal anomaly, I tried to search out its possible causes. I found many interesting anomalies in the field of tidal theory. In fact, tidal theory, itself, is a fascinating study. Most people know the basic facts about tides—there are usually two per day, the times and range of which vary from day to day. Yet, an understanding of even these basic facts involves principles from two quite separate fields—astronomy and hydrodynamics.

Astronomically, two facts illustrate that the tides are dominated by the movement of the moon. First, the times when high tides occur are linked to the daily motion of the moon. Second, certain features of the tide are governed by the moon's phases and the varying distance from the moon to the earth. It is also clear, from variations in the times and heights of tides, that the sun plays its part.

However, gravitation cannot be the *specific* cause of tides. If it were the major factor, then solar tides would predominate. For it can be shown that, on the earth, the force of gravitation from the sun is some 167 times greater than the force of gravitation from the moon. Although the moon is a close neighbor—indeed, a satellite of the earth—the tremendous mass of the sun, even at its vastly greater distance from the earth, produces the dominant gravitational force. But, paradoxically, the tides produced by the moon are more than twice the range of the solar tides.

The cause of this seeming paradox, actually, is the difference in the nearby moon's gravitational attraction for *different* parts of the earth. That part of the earth lying directly under the moon at any time is some four thousand miles closer to the moon than is the earth's center, and the earth's center, in turn, is some four thousand miles closer than the earth's surface on the opposite side.

GRAVITATION acts on our solid planet as though all of the earth's mass were concentrated at its center. But the particles that comprise the water shell upon the earth's surface—the oceans, principally, which cover over seventy per cent of the area—react to these differences in the moon's relatively weak gravitational force. The free-moving water molecules of the oceans on the side of the earth closest to the moon pile up, so to speak, in a "bulge" under our satellite. And another "bulge" is produced on the side of the earth opposite to the moon (illustration, left). One might say that, on the moon's side, the ocean is "pulled" away from the solid earth, while, on the opposite side, the earth is in turn "pulled" away from the ocean.

As the moon revolves around the earth each month, these two moon-induced bulges follow it. If we imagine the earth to be stationary, there would be only two high tides in each lunar month. But, the earth is also rotating — once round each day. Now, each place on the earth's surface should pass through the pair of moon-induced bulges every twenty-four hours. But the bulges are also carried forward a certain amount each day by the daily progress of the moon's revolution (illustrations, pp. 328-29, top). Because the moon is leading the pair of bulges round the earth

MR. NICHOLSON, an astronomer of THE AMERICAN MUSEUM-HAYDEN PLANETARIUM, had become a Chief Officer aboard merchantmen before he reached voting age. He has drawn on both these backgrounds in preparing this discussion.

once a month. in the same direction as the earth's rotation, it takes *more* than twenty-four hours for each place on earth to pass through the pair. As we have seen, twenty-four hours and fifty minutes is the average time.

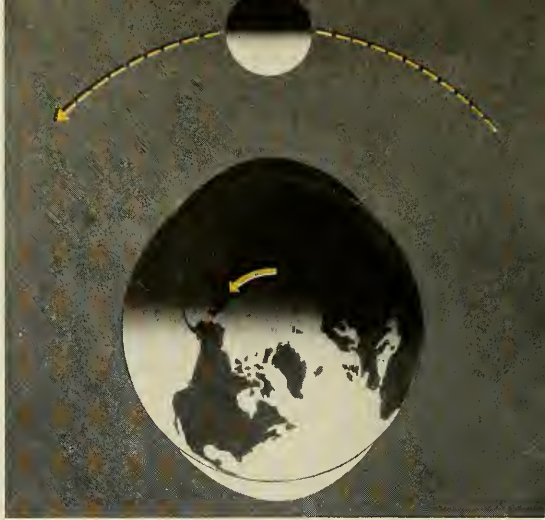
The daily rotation of the earth has another effect. This movement displaces the bulges forward of their "normal" position, which should be in line with the moon. The earth is rotating at a far faster rate than the moon is moving tidal bulges across the surface. Thus, the tides are carried forward in the direction of the earth's rotation. High tides do not occur, in consequence, for several hours *after* the moon appears over a particular point on the earth's surface. This difference in time between the moon's passage overhead and the high tide's appearance (known as the high-water lunitidal interval) varies widely from place to place on earth, although it does not change much from day to day at any given location.

The weaker tides on the earth produced by the sun are similar to the lunar tides. The bulges are formed in the oceans, one directly under the sun and one on the opposite side of the earth. The effect of these solar bulges may be superimposed on the lunar tides, but the two are usually out of phase, because the sun and the moon generally stand in different directions from the earth.

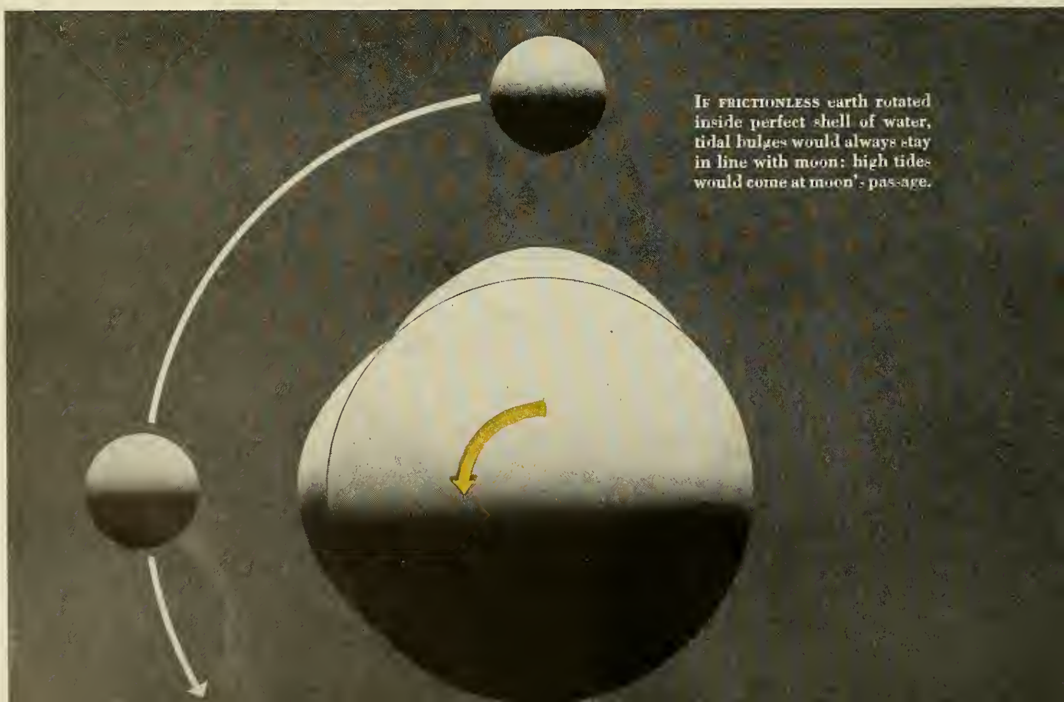
Twice each month, however, the sun and moon stand either in the same direction (at new moon) or in opposite directions (at full moon). At these times, the lunar high tides coincide with the solar high tides: the resultant high tide is some twenty per cent greater than usual. These "in phase" tides, known as the "spring tides," occur at intervals of about two weeks (in spite of their name, the "spring tides" have nothing to do with the spring season).

At two other times during the month, the tides of the sun and moon are exactly "out of phase": that is, lunar high tide coincides with solar low tide. This happens when the sun and moon are 90° apart in the sky (the time when the moon is at first or last quarter, and the quadrature of our Tahitian example). Tides are then less than normal, with lower high tides and higher low tides. These twice monthly "out of phase" occurrences, in turn, are known as the "neap" tides (see illustrations, p. 330).

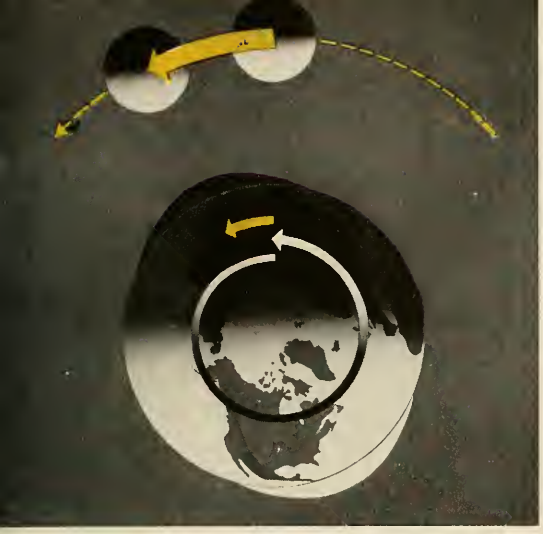
The cycle of the moon's phases, therefore, is accompanied by a cycle in the range of tides. At new moon, spring tides are greater than normal. About a week later, at first



WITH A MOTIONLESS MOON, earth's rotation would bring high tides at the same hour each day, *above*. But moon's



IF FRICTIONLESS earth rotated inside perfect shell of water, tidal bulges would always stay in line with moon: high tides would come at moon's passage.



advance in orbit, *above*, shifts bulges eastward each day and earth must rotate an extra fifty minutes to catch up.

quarter moon, the neap tides are lower. Another week brings full moon and another spring tide. Again about a week later, last quarter moon brings another neap tide, and the cycle begins again in a week with the next new moon.

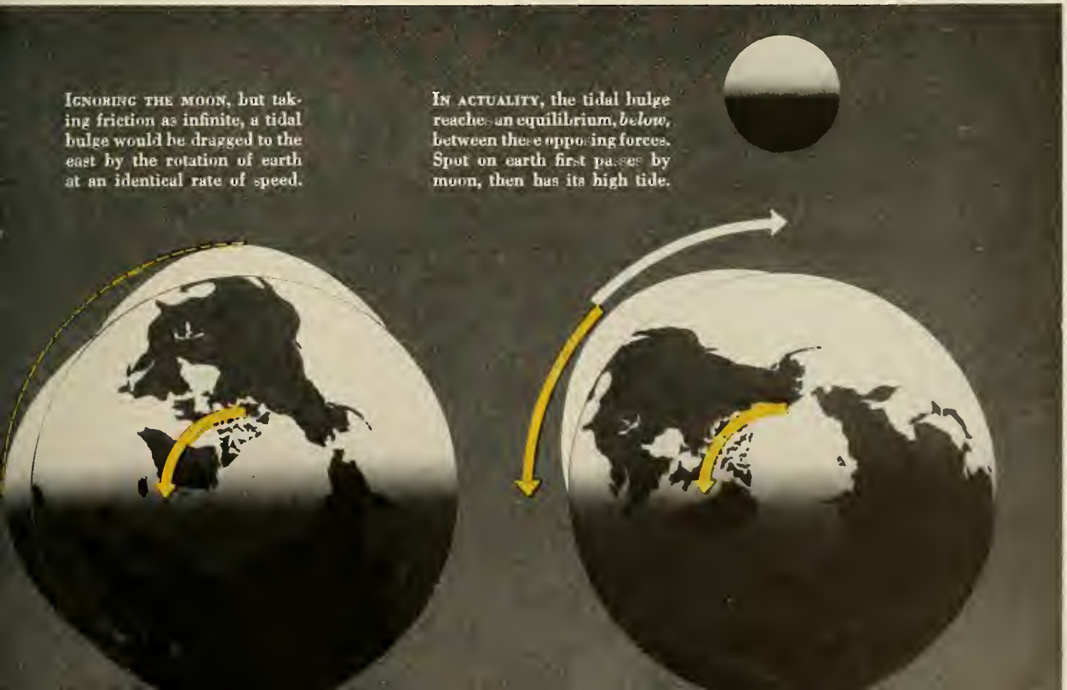
Between the alternating cycle of spring and neap tides, the principal effect of solar gravitation is to "prime" or "lag" the tides. This is to say that the sun's action causes high tides to come earlier or later than they would normally, so that the actual tidal day varies somewhat from its average twenty-four hours and fifty minutes.

The orbit of the moon around the earth, of course, is elliptical rather than circular. Thus, the moon constantly varies in position from being closest to the earth—the point called "perigee"—and farthest away—the point called "apogee." The *average* distance is about 239,000 miles: at perigee, the moon is nearly 15,000 miles closer and, at apogee, 15,000 miles farther away. These variations in lunar distance also have their effects on the tides. At perigee, the tides are about twenty per cent greater than usual: at apogee some twenty per cent less.

But perigee and apogee occur about two weeks apart, and are usually out of phase with new moon and full moon (that is, as we have seen, the times when lunar and solar tides are in phase). At the same time, perigee very nearly coincides with either new moon or full moon at least twice each year, and this coincidence brings about even greater tides. When the moon is at perigee at the same time that its phase is new or full, the perigee tides are added to the spring tides, and high water can be about forty per cent higher than normal. If severe storms or winds from adverse directions should occur at the same time, the piling-up of waters, added to the unusually great tide, can often result in damaging flood conditions along low-lying coastal areas. This has happened several times in recent years along the Northeast Coast of the United States.

Perigee spring tides can be forecast long in advance—years if necessary—from the known motions of the sun and moon. The winds are not so certain, of course, but these are times for cautious watching along the coast. Perigee spring tides occurred on May 22 this year and can be forecast for December 29, 1959, and for July 8, in 1960.

The varying distances from the sun to the earth also produce small differences in the solar tides. The earth is closest to the sun in early January—about a million and a half miles closer than the average. Although the effect is small,



IGNORING THE MOON, but taking friction as infinite, a tidal bulge would be dragged to the east by the rotation of earth at an identical rate of speed.

IN ACTUALITY, the tidal bulge reaches an equilibrium, *below*, between these opposing forces. Spot on earth first passes by moon, then has its high tide.

the greatest range of tides can occur when perigee spring tides coincide with maximum solar tides.

In most of the tide waters of the earth, there are two high tides per day, nearly equal in height: such tides are called "semidiurnal." Some places experience only one high tide per day, however, and have what are called "diurnal" tides. In many places, tides are "mixed," semidiurnal for part of the month and diurnal for part of the month. But even in places that always have two high tides per day, there are times during the month when the heights of the two tides are considerably different. These tidal variations can be attributed to what is known as the "semidiurnal inequality" of the tides.

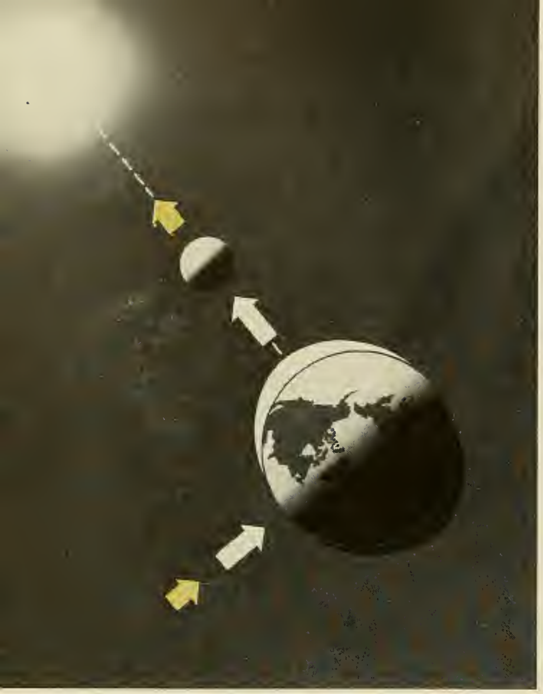
The orbit of the moon around the earth is inclined by about 5° to the plane of the earth's orbit around the sun. The earth's orbit, in turn, is inclined by about 23½° to the plane of the equator. Twice a month, the moon is over the equator, but its orbit takes it, at other times, as much as 28½° above or below the equator. When the moon is near its greatest distance above or below the equator, it is said to be "in its tropics"—a reference to the fact that it is near the Tropic of Cancer, north, or the Tropic of Capricorn, south of the equator. At such times as this, the two tidal bulges produced by the moon are not symmetrical with the equator: instead, the axis between the two passes considerably north and south. This displacement of the tidal bulges above or below the equator produces the variation—or semidiurnal inequality—in the heights of the two daily high tides (illustrations, right).

This inequality is most pronounced in high latitudes at the times, each month, when the moon reaches its greatest distance north or south of the equator. For some points the inequality becomes so great that one of the high tides practically disappears and becomes, at most, only a slight fluctuation in the low tide. The tide then becomes diurnal—that is, only one high tide each day. The diurnal type of tide is a regular feature twice each month along the Gulf Coast and West Coast of the United States.

Tides are most often considered to be the rise and fall of the earth's waters. Actually they are far more; the effect of tidal forces is felt on the entire earth. And there is a secondary feature of the tides even in the oceans. There are horizontal movements of the water—tidal currents—which accompany the rise and fall.

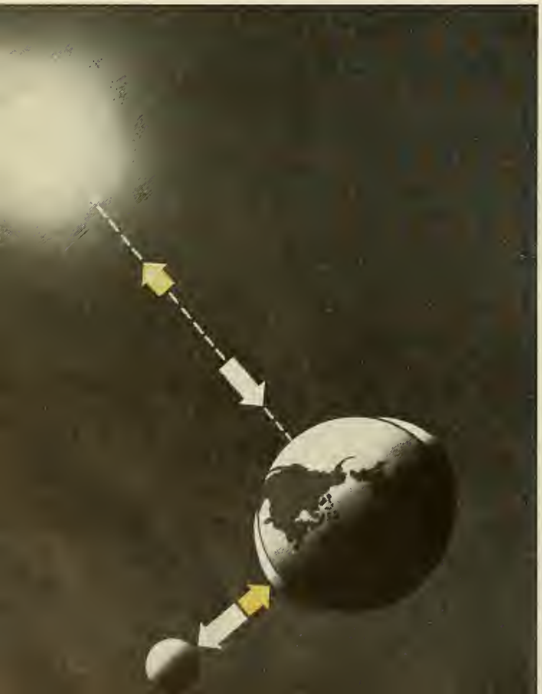
The currents that accompany tides are most pronounced in inlets from the oceans—such as bays or gulfs—and in channels between larger bodies of water. They are present—though relatively weak—along straight coast lines, but they are not detectable in the open oceans. Along the shore, flood currents are associated with a rising tide, and ebb currents accompany a falling tide. There are usually slack periods of no current about the time when the tides change, but these slack periods may not coincide exactly with the times of high or low water. Tidal currents can reach considerable velocities in areas where the tides are also great, as for example in Pentland Firth, north of Scotland, where tidal currents can reach a velocity of more than nine miles per hour.

There are tides in the solid earth, and in the earth's atmosphere as well. Atmospheric tides have been detected through careful analysis of changes in the barometer. And earth tides have been measured by experiments with tidal forces in completely enclosed, long, water-filled pipes.



Spring tides, with greater than normal range, occur when moon and sun are in the same, *above*, or opposite direction from earth, and lunar and solar tidal forces thus coincide.

Neap tides, with less than normal range, are a result of lunar and solar forces working at right angles, *below*. In this event, a solar low modifies lunar high, and vice versa.



It is estimated that the level of the solid earth fluctuates as much as nine inches during times of spring tides. The most evident tidal effect, though, and the one that influences civilization far more than the others, is the vertical tide in the oceans and their adjacent waterways.

Although astronomical explanations account nicely for the basic mechanics of tides—and also for some of their variations—they cannot hope to account for the wide range of tidal conditions that exist in the earth's oceans. If the earth were a perfect sphere, covered with an ocean of uniform depth, the tides might take place in exact accord with astronomical principles. But the earth, of course, is no such thing. Its oceans are irregular in shape, depth, and extent. Great undersea mountain ranges, deep basins, partly landlocked bays and seas, narrow channels between large bodies of water, and irregular coast lines—some shoaling gradually and others steeply—modify the progression of normal tides from ideal, wavelike formations round a perfect water-world.

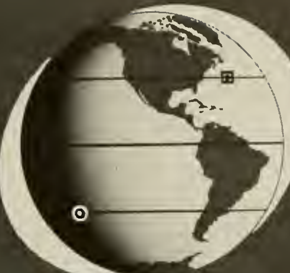
No purely astronomical theory of the tides, for example, could ever explain why high tides in the Societies follow the sun every day, coming at noon and midnight. Local tidal conditions, even in such vast ocean areas as the Pacific, can be explained—if, in the present state of our knowledge, they can be explained at all—only in terms of the science of hydrodynamics.

Some unusual tides are produced by a rapidly building water supply, undergoing forced restriction by the shape of adjacent land features. The strange tidal bores (walls of water that progress up some river deltas), the unusual range of tides in the Bay of Fundy area (up to fifty feet between high and low), the great tides and tidal currents around England and the channel ports of Europe (where very narrow channels connect the shallow North Sea with the open Atlantic), all these phenomena simply represent a flow of water under the force of hydraulic pressure.

Two basic theories, in accord with hydrodynamic principles, have been presented to explain the wide range of tidal conditions observed throughout the world. These are the progressive wave and the stationary wave theories. In both it is assumed that the tidal forces of the sun and moon set up wave conditions in the open areas of the oceans. Progressive waves are those that travel through the water, like ripples in a pond. Stationary waves are those that oscillate, rising at one end while falling at the other, like the oscillation that can be produced in a pan of water by alternately raising and lowering one end.

The tides that occur in the two major basins of the Atlantic Ocean suggest that progressive waves are generated in the southern area and move northward—through both the South and the North Atlantic. Cotidal lines—joining those places where high tides occur at the same time—indicate, progressively later tides northward from the southern ocean. But certain secondary features of the tide—such as the variations at perigee and apogee moon, or with spring and neap tides—occur almost simultaneously throughout the Atlantic. In a simple progressive wave action, these features should also appear at later intervals as the wave in which they were generated traveled along the coasts. Thus, the progressive wave theory *almost*, but does not quite, explain the Atlantic tides.

The progressive wave theory *could* account for the unusual tides in the Society Islands. Two such waves, coming from different directions, *could* have lunar con-



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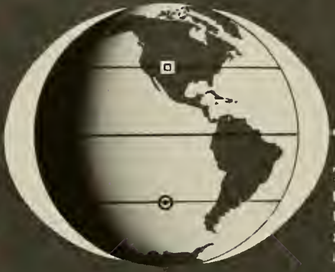

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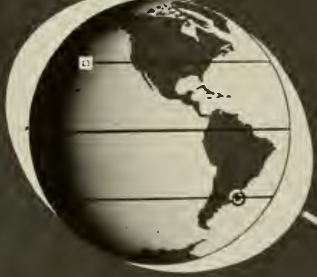

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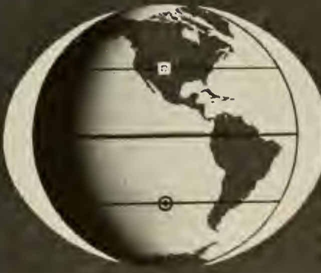

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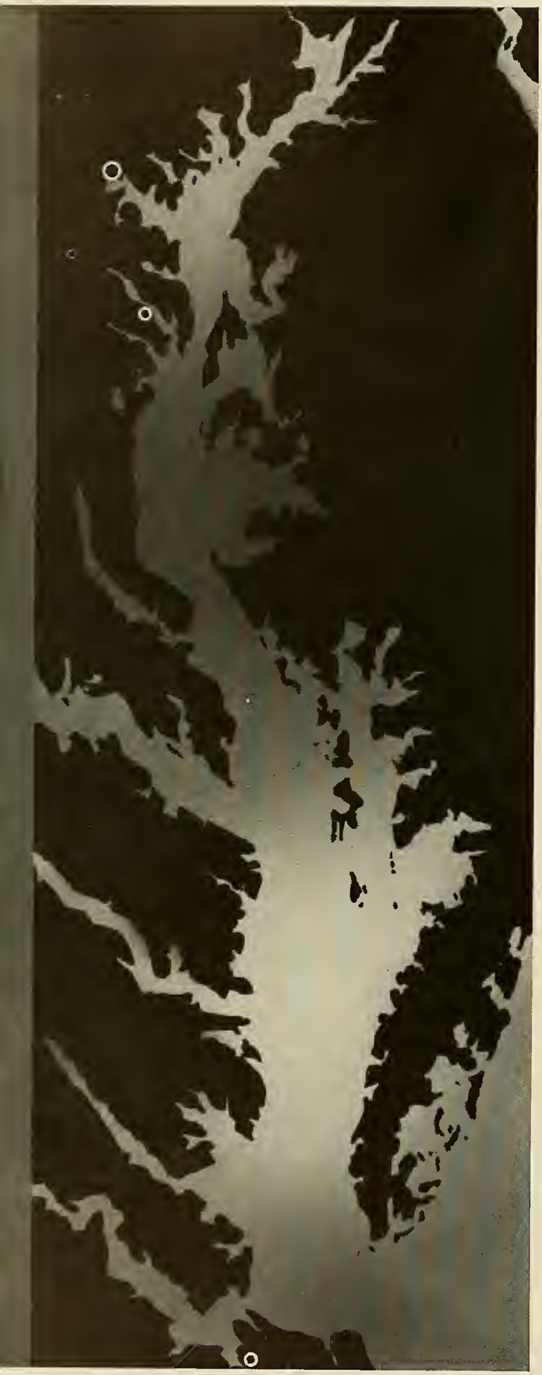


Progressive wave theory is illustrated, in miniature, by tides in Chesapeake Bay. Here, tide is high near mouth and at head, low at Easton. Ships can ride flood up whole Bay.

stituents (of approximately equal range but exactly six hours apart in phase) so that, at Tahiti, the high tide of one would coincide with the low tide of the other. Only the solar tide, under these circumstances, would show a rise and fall, and the time of these tides would follow the sun's transits at regular twelve-hour intervals. But no apparent cause for such a pair of progressive waves can be shown, nor is there any apparent physical reason to explain why such hypothetical progressive waves should meet near the Society Islands rather than at other places in the Pacific.

Although some local tidal phenomena can still be explained by assuming progressive wave action, this view has largely been discarded as a general theory accounting for tidal features on a broad scale. Considerably more evidence can be brought to support a theory based on the existence of large, stationary waves in the ocean basins.

In a stationary wave, the two ends of a body of water oscillate in exact phase opposition: when one end is high, the other is low; there is a line approximately in the center—the node—where no change takes place. Once such waves are set in motion, it takes very little force—synchronized with the natural period of vibration for the size of the water body—to sustain the action.

It is quite possible that such resonant oscillations can be sustained in large, oceanic bodies of water by a very small periodic force, provided that the period of the force and the natural, resonant period of the water-body are fairly close, and also provided that the water-body is sufficiently confined so that no great amount of energy is carried away by progressive waves. The oceans, by reason of their depths and the configurations of their coast lines and subsurface contours, contain areas where such dynamic systems could have periods of resonance nearly equal to the periods of the gravitational forces.

In a classic document—the "Manual of Tides," presented as part of the *Report of the Superintendent of the U. S. Coast and Geodetic Survey* for the years 1897-1904—Dr. R. A. Harris divided the oceans of the world into oscillating areas, in which the periods of free oscillation would be about equal to the periods of the diurnal or semidiurnal tide-producing forces of the sun and moon. Harris' areas were selected so that the observed differences in the time of high water at both ends of an area would be approximately six or twelve hours. This half-century-old division of the oceans into "oscillating systems," while not a perfect explanation for all observed tides, brought a surprising degree of consistency in an otherwise confused picture of the tides, and helped to explain many apparently paradoxical tidal phenomena.

The identification of an ocean basin as an oscillating system is based partly on the observed physical features of the basin, such as depth, length, and shape, and partly on an observation of tidal data consistent with the features of a stationary wave. The greatest range of tides should be observed at the extremes of the wave, with very little or no range near the node (the line about which the system oscillates). On one side of the node, high tides should come at nearly the same time, while low tides would occur simultaneously on the other side.

For different components of the tide-producing forces, the oceans would oscillate differently, since these components would have different periods. Some such systems would oscillate in the period of the lunar semidiurnal tide, others in the period of the solar semidiurnal tide. Still other basins, with suitable features and natural resonant periods, would oscillate instead with the periods of the lunar or solar diurnal tides.

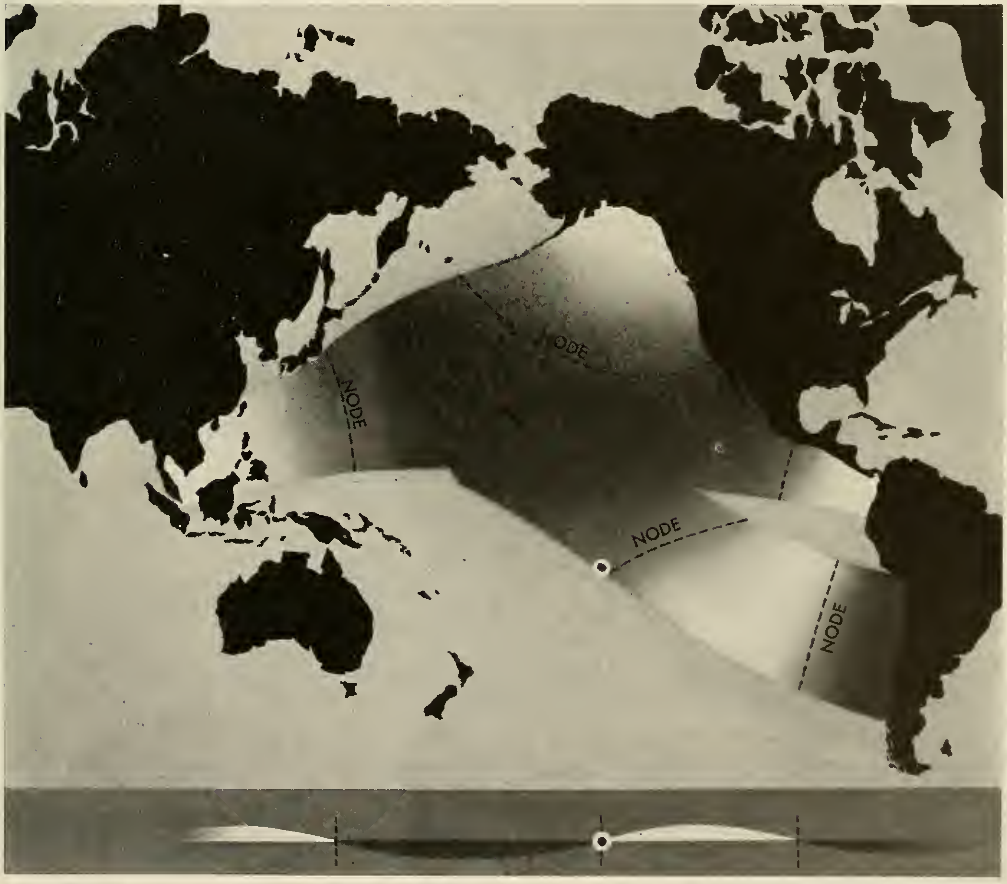
The stationary wave theory—perhaps better than its progressive wave counterpart—accounts for the peculiar tides of Tahiti by assuming that the Society Islands lie on or close to the node of a stationary wave that has a period equal to the semidiurnal tidal force of the moon. There is evidence that such a wave exists in the area and that the node, extending in a gradual curve with the general direction ENE and WSW, does lie close to the Societies. It can be shown that the tides to the northwest and southeast have greater ranges than those at the Society Islands, and that they are out of phase, high tides in one direction corresponding to low tides in the other.

Positions close to the node of a stationary wave should not experience a rise and fall of any significant amount. Thus, the absence of a lunar semidiurnal feature in the tides at Tahiti would be normal. On the other hand, Tahiti is remote from the node of the assumed wave responding to the solar semidiurnal component. Therefore, the tidal rise and fall at the island should take place principally in response to solar tidal force.

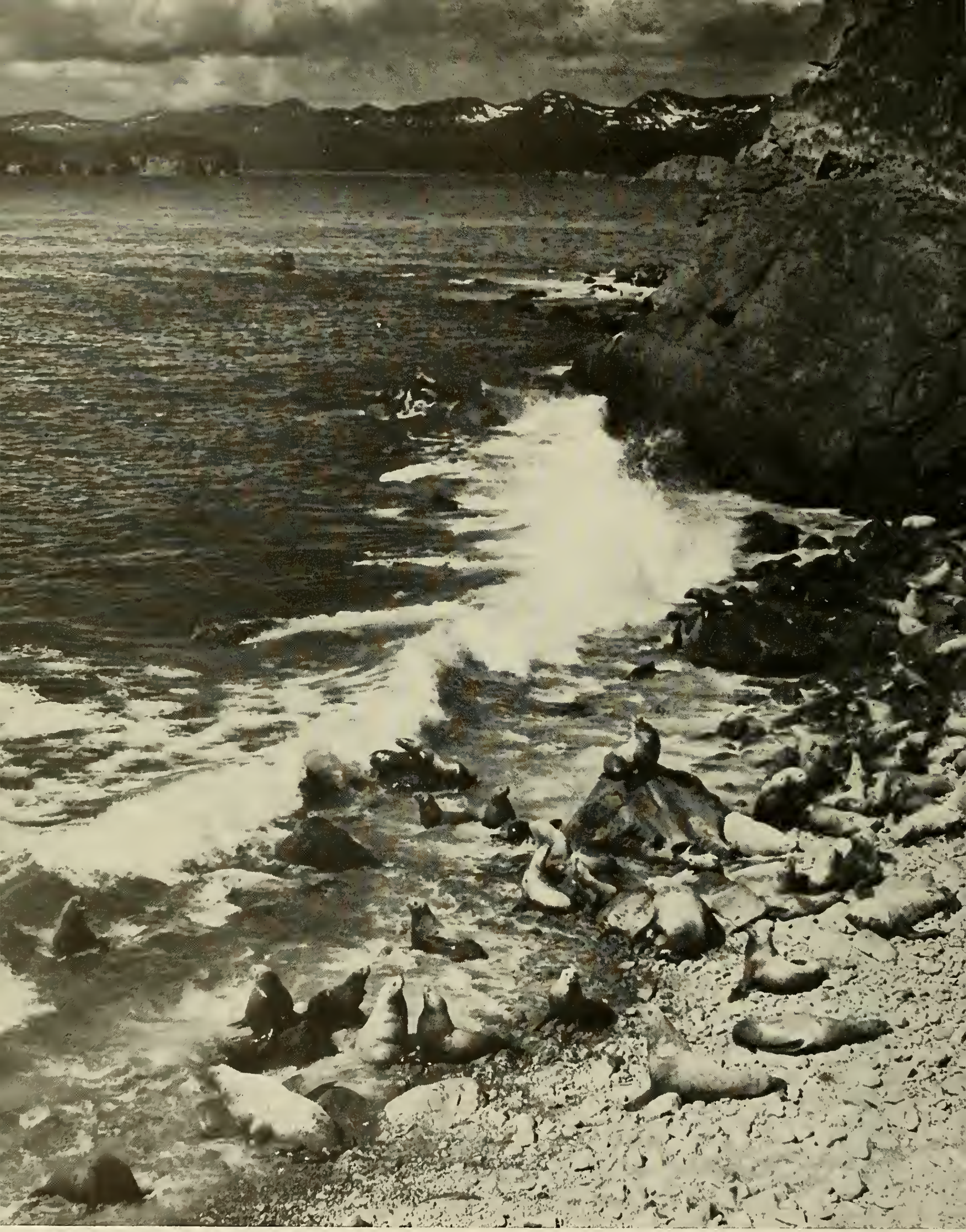
SUCH oscillating systems belong to the open oceans. Islands like Tahiti, far distant from any great irregularity in ocean shape, should illustrate the effect of such a tidal theory more closely than would other, less open positions, where secondary, progressive waves are most likely to affect the observed data.

Elsewhere in the world, the ocean tides continue to reflect the daily retardation impressed by the moon's motion. Thus, in tidal phenomena, the Society Islands stand—as they have, since discovery—for a romantic escape from realism, although much of their tidal romanticism has been stripped away by the logic of science.

(A discussion of terrestrial elements affecting the tides will soon appear in NATURAL HISTORY.)



STANDING WAVE THEORY is seen here for the Pacific Basin. Dashed lines represent "nodes" of five different standing waves. Dark areas represent low tides on one side of each nodal line, matched in each case by reciprocal high tides (bright areas) on opposite side. Society Islands (dot) lie adjacent to the node of one such postulated standing wave.



Rookery islet, in Prince William Sound, Alaska, is home for almost 2,000 Steller sea lions. Except for this short stretch of rocky beach, which is common ground, rookery is sharply subdivided into many harem and pupping areas.

ALASKAN CHALLENGERS OF THE SEA

The highly specialized Steller sea lion must compete with his neighbor, weather, and man

By G. M. Daetz

SLATE GRAY at birth, pups are brown at seven months, gold-brown when adults.

THE NUMBERS of sea lions living today, of course, are only a fraction of what the offshore islands of North America and Asia once held. The smaller, southern one, the California sea lion, *Zalophus californianus*, survives in greatly reduced numbers. The Steller, or Northern sea lion, *Eumetopias jubata*, is one of the larger carnivores in the world (the bulls weigh an average of 1,200 pounds and the cows, 500). These giants are also steadily diminishing.

With all the great ocean for the Stellers to live in, one would think they could live, increasing and multiplying, anywhere there were fish. Actually, they have so many limiting specializations that it is somewhat surprising they have held out — big animals in competition with civilization—as well as they have. Although they concentrate in offshore rookeries — to be found from St. Lawrence Island, off the Alaska coast, to the southern waters of the state of California—very little was known of their life history until recently.

Now, in Alaska — their major remaining stronghold — the Stellers are unprotected. Fishing and cannery groups include the sea lions among the many wildlife competitors for the reduced number of salmon left in these overfished waters. Thus, the recluse Steller finds himself in competition with civilization. Meanwhile, zoological researchers — in Alaska, Canada, the Soviet Union, and the United States—are descending upon the more accessible rookeries to learn about sea lions.

In the summer of 1957, I had the privilege of serving, as a very small cog in one of these wheels of research, as a field assistant to Dr. James W. Brooks, the senior biologist of the Alaska Department of Fish and Game. Dr. Brooks's studies are continuing and, from this Alaskan work — and other studies in North America and the U.S.S.R. — the factual basis for civilization's possible coexistence with the Steller sea lion, rather than for the animal's ruthless extinction by mankind, is perhaps being laid.

ON the day that Dr. Brooks completed his studies at the five-acre Rookery Islet, off Montague Island, Prince William Sound, I like to imagine that a windy sigh of relief went up from two thousand sea-lion throats. It would have been justified, for our summer's work disturbed them a lot.

These big, northern predators start life in the month of June, weighing about forty pounds at birth. The Steller pup has a thick, slate-gray coat that happens to blend excellently with the rocks on which it is whelped. This color changes to dark brown in six months and—by the end of its second year—lightens to the yellow-gold back and red-brown belly usually seen in adults. Color, of course, is a variable characteristic — some big adolescents still are brown.

A yearling Steller is active, pesky, likable, and still nursing. These 175- to 210-pound youngsters evidently still live almost exclusively on their mothers' milk. No yearling's stomach that we examined had any variety of food other than milk in it.

On the rookery, we noticed one yearling, orphaned by gunfire. In two weeks, he was easily identifiable by his emaciated appearance. One would think that, with his normal size — an estimated 170 pounds — and his unquestionable swimming ability, he would have caught fish. And fish were easily available: shoals of herring swept through the rookery area, and we caught greenling and black rock fish in shallow water (three to four fathoms) offshore as fast as a hook could be baited. But from him we learned that even yearlings must nurse to survive. He was an aggressive youngster, and his hungry approaches to lactating cows would be met savagely. The cows seized and shook him if he persisted. But he would not give up. Howling from hunger and marked by ugly bite wounds, he tried

MR. DAETZ spent the summer of 1957 as field assistant to Dr. J. W. Brooks, senior biologist of the Alaska Fish and Game Department, who is engaged in continuing studies of sea lions.

Bull sea lion has found a bare, unguarded rock and taken possession of it. From this eminence, he repeats his low-pitched bellow to attract a female. Here, one answers him, and her emergence from the water marks start of his harem.

to nurse one lactating female and then another—without success.

The young Steller's lengthy nursing period must serve to give it a healthy, running start in life. For its first bite of fish is likely to contain the tapeworm larvae or roundworms that will begin the sea lion's permanent parasitization. A mature Steller's small intestine usually has tapeworms along its full length. Sometimes the intestine is crammed with them. The stomach is almost invariably well populated by clusters of roundworms.

For the tapeworms, the cycle is a simple one. In the rock pools of every rookery, tapeworm proglottids are thickly strewn. Waves come up and wash them into the sea, where they are eaten by crustaceans and fish (their hosts in the larval stage). Eventually, as the sea lions feed on the fish, the cycle is completed and the parasites become energy-draining adults within the sea lion's intestinal tract. At first glance, this inevitable, heavy parasitization makes one wonder how the sea lions can survive. But after dissecting bulls in the height of good health — and finding them heavily infested — the observer must conclude that it is a mighty poor sea lion that cannot support a few dozen eight-foot tapeworms, plus the usual ascarid population.

In spite of their heavy parasitization, the Steller sea lions possess a good insulating layer of subcutaneous fat: it lies one-quarter to three-quarters of an inch thick in the summertime. Their robust physiques and excellent co-ordination make amazing athletic feats look easy. Diving from great heights into the water is elementary. A Steller can also plunge its half-ton of weight on to unyielding rock from a height of as much as twenty feet. The stout-boned front flippers take much of the shock, and the springy, cartilaginous ribs bend like thick rubber: these ribs contain so little ossified material that an ordinary knife can cut cleanly and easily through them.

As one measure of the sea lion's fitness in its environment, consider that a mother can catch fish enough to feed herself, nurse her young, nourish her parasites and remain in fat layer and splendid coat—and still spend all but two or three hours a day lying sleepily on the rocks or arguing with her neighbors.

Deliberate and slow-moving on land, if not in a hurry, and with an underwater speed of only seventeen to eighteen miles per hour, the sea lion's qualification as an expert fisherman is due in part to its incredibly swift strike. On land, fighting among themselves, a sea lion's neck and head will flash forward and back so quickly that the strike appears to have been perhaps no more than a threatening gesture — until blood begins to flow from an opened slash in the thick hide of the adversary.

In picking up two-week-old pups by the hind flippers to weigh them, we found even these young could deliver a solid, swift blow. The pups were very friendly if not alarmed, but we did not always have time to reassure them. There would be a quick strike and the feeling of having been touched. The handler would say, "That was close!" then look in surprise at a blood blister forming where

Bachelor bull, *above*, challenging rock's defender, meets fierce roar, hisses, and lightning slashes of powerful incisors.

Sea lion family, *below*, huddles precariously on a rock. An average bull weighs around 1,200 lbs., a cow about 500.

the pup's nip had pinched his skin.

Although size and shape differentiate the sexes easily, both male and female are beautifully adapted to give a minimal resistance to water flow. The bull's massive shoulders form the wide part of a teardrop form. He tapers down to a thin pelvis and flat hind-flippers. There are no external genitalia to break his smooth surface-contour ventrally: in the posterior abdominal area, a slit in the skin, as neat as a zipper, serves as the opening for the genitalia.

In the cow, both vaginal and rectal openings lie beneath the four-inch tail stub between the hind flippers. Nor is it possible to tell at a glance whether or not a female is lactating. The nipples of the mammary glands are completely retractable: they show only as small, hairless spots on either side of the abdomen. Only under the stimulus of the calf's nuzzling do they evert to something over an inch in length. The milk-producing tissue locally replaces the usual subcutaneous fat layer in lactating females, covering the abdomen as a thick layer.

Some females have four functioning teats; some have six—and it is not unusual to find five. The pup or yearling (no twins were seen) works up and down the system, biting and pestering his sleepy mother until she assumes a suitable nursing position.

Some adult Steller feeding habits are surprising, but the animal's lengthy small intestine (200 feet) gives ingested food a long trip, during which it can be assimilated. The most readily available shallow-water fish were found in the stomachs we examined but one would not have predicted the discovery of whole clams (as others have reported) or ordinary beach stones—from one to three inches in diameter—of which we found a few in almost half the stomachs we examined that summer. Such stones are known to have one useful purpose—to provide subjects for biological speculation.

One would expect the Stellers at Prince William Sound to disturb the extensive halibut fishing operations, which are carried on as little as half a mile away from the population of two thousand sea lions at Rookery Islet. Yet not a fisherman near the rookery lost any halibut to the Stellers: the sea around the rookery, during breeding season, is also alive with herring, greenling, and black rock fish. These were the fish in the Stellers' stomachs.

Coming in from feeding, the sea lions flip out of the salt water onto the rock ledges and dry off. They visibly change color and form—from a wet, slim, slick tan to a thicker, furry, yellow-gold color. And they dry easily on damp days or in a drizzle. When our own clothing became wet, coming in through the surf, we were lucky to have it dry by the end of the day: the sea lions dried off in less than an hour. A close inspection of the Steller's pelt shows how this is possible. The hair on a ten-foot, adult bull will vary from one and a half inches in length (at the coarse mane of his neck) to finer, half-inch hair near the tail. When wet, the hair lies flat in the direction of the water flow past the body. But, as soon as drying begins, the hair tips curve forward. At the slightest drying, each hair stands individually erect. Unscientifically, we may call this the "crew-cut effect": combined with the sea lions' body heat, it dries their coats in a half-hour, even during a light drizzle.

The question of how often a Steller female bears young—and how many in a lifetime—is still being studied by Dr. Brooks. What is known from his past observations is this: those females that are nursing yearlings at pupping time (the month of June) are not carrying a fetus. Thus, they definitely do *not* whelp every year. It may even prove that Steller females nurse longer than one year and do not mate for two consecutive years after whelping. It is also possible, however, that the females we saw nursing yearlings in June will have weaned them before autumn and be free to mate in October. Soviet research indicates that the fertilized sea lion egg implants in the uterus in October. Delayed implantation of fertilized eggs is not uncommon in sea mammals, so that—roughly—a nine-month gestation period appears in order, whether mating is in June or later in the season.

Like many other large, predatory animals, the sea lion—competent in his natural role—has not adjusted to being the hunted, rather than the hunter. Pitted against man, the sea lion's sight, hearing, sense of smell and alertness to danger on land all fall short of the survival level for a lone individual. Still, the Steller's gregarious habits help somewhat in protecting the group—usually, some alert sea lion will warn the sleepers.

The sea lion's eyes, being adapted to underwater use, are myopic in air. I have found them unaware of my presence, although I was sitting openly on rocks quite near them, as long as I stayed still. When I moved, enabling them to spot me, the half-ton Stellers fled in panic. Their eyes have no protecting bony, supraorbital ridge such as we have. Blindness—evidenced by opacity of the eye—is not uncommon among them. The contentions among adult sea lions—with attendant snapping and biting—are a source of much eye and other bodily injury.

Although the Stellers have not progressed in their smooth contouring to the point of having the whole ear internal, as do the hair seals, their external ears are very small. Yet, they depend on their hearing, on land as well as in the water: mother and pup call to each other, and the colony as a whole apparently utilizes a variety of roars, barks, and grunts. The animals also react to such sounds as the rattle of a dislodged stone, motor exhaust, or rifle shot.

The Stellers are gregarious animals. In early summer, especially, they congregate by the hundreds, and even thousands, on their select rock ledges. At a casual glance, the big rookery where we studied the Stellers looked something like a church picnic, complete with portly, dignified males, frolicking youngsters and watchful mothers. Watching the sea lions for a while, however, we soon realized that the gathering was far from a general fraternization. Except for a short gravel beach, that we named "The

A Steller, traveling at a high speed, thrusts its head briefly above water to inhale and exhale. Sea lions seldom stay submerged more than five minutes.

Storm's approach, *above*, finds bull and harem still safe above the waves, but rising seas, *below*, force harem to leave rookery despite bull's protests.

Commons," the rookery area was strictly divided into mating and pupping areas. The mating areas, in turn, were subdivided into small plots, each dominated by a harem bull.

The Commons was public. Any age and sex of animal, excepting newborn, could be found on that beach: cows and their yearlings, just in from the Pacific; young bulls—three, four, and five years old and not yet strong enough to fight for a harem territory; and, sitting out the summer, old bulls, macerated and driven from their harems by young rivals.

Around the greater circumference of the rookery island, table-like rocks held the usual adult harems—comprised of six to a dozen cows, their yearlings (and possibly some two-year-olds belonging to some of the cows), and a single, adult bull. The size of the harem each bull could gather about him varied inversely to the harem's degree of accessibility. On a ten-by-twenty-foot, sheer-sided rock, we have seen a bull hold as many as fourteen cows—because of the area's easy defensibility. More often, a bull's original claim of territory would prove too big, or too accessible, to prevent rivals from gaining good fighting position. In such cases, the rock would be subdivided into several harem territories, each bull defending a segment of the rock both from his neighbors on land and, more importantly, from infiltration by sea.

For, lying out at a respectful distance in the water, or cruising stealthily to the edge of the rock harems, were always a number of bachelor bulls—graduates of The Commons—waiting their chance. A harem bull would take his daytime naps, but during the sunrise and sunset hours—when all the sea lions were most active — he watched continually. When a bachelor swam close in, the harem bull would shift into position to dive down, and the intruder would speed off like a torpedo.

Tide and waves become higher. Upper rocks become crowded with evacuees as each bull struggles to keep his harem community intact. At nightfall, *above,*

We seldom saw an older harem bull give underwater chase to the young intruders. It was far more usual to deal with challengers as they tried to scale the rock. With the advantage of height, it did not take an especially vigorous bull to drive off contenders. But young harem bulls would often launch out in a mighty dive to deal with cruising bachelors—especially if the strange bull was pursuing a swimming cow. The risk involved in this defense by attack was that the harem bull might return to find another stranger already ashore in his territory.

The small communities on the offshore rocks were remarkably stable. If a female newcomer appeared, it caused a commotion among the established cows until the new female found a spot suitably distant from them—about four feet. And the bull stepped in immediately to break up any actual fights between cows—nodding and giving short, low, conciliatory grunts, such as sea lions use with their young. If a new bull climbed surreptitiously onto the

the storm still rages. Of the animals seen on the previous page only the old bull holds his ground until he, too, is finally swept off by the waves. After the storm has abated he will have to fight to regain his previous position.

rock, the cows were not disturbed—providing he showed some care in the way he placed his flippers amidst the crowd. But the intruder would be lucky to get that far: the harem bull had a different attitude. Usually before the newcomer could gain a level spot from which to fight, the harem bull, with a loud roar and hiss, would undertake a heavy rolling-shouldered charge. The cows would scatter or be trampled. Even the most eager young bachelor would usually swirl off underwater.

The cows have little loyalty to the harem. It is the bull's problem to keep as many potential mates as possible. He inspects each female who comes aboard his rock territory—and is usually rewarded with a snap of the cow's teeth, the severity of which may indicate the degree to which she wishes to be left alone, for sometimes she only tugs playfully at his massive neck. Mating usually takes place in the harem

Restless, but still sleepy, Steller did not hear alarm given by more alert sea lion at author's approach. Myopic eyes search for the source of danger.

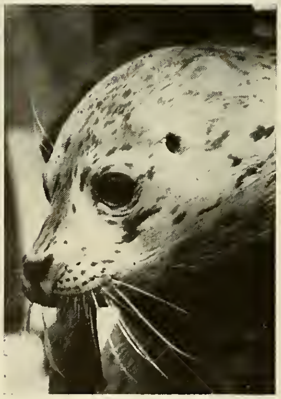
Recognizing a potential enemy, the sea lion pulls himself upright, shows

areas, but we have seen mating completed in the water.

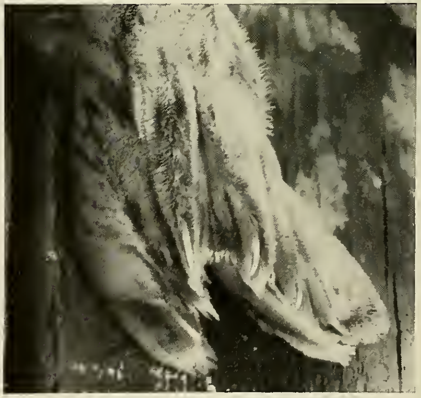
The major pupping area at Rookery Islet is a great shelf of boulder-strewn rock on the landward side: the mighty seas sweeping in from the Gulf of Alaska cannot climb up onto this shelf in full fury. It gives shelter above high tide to almost eight hundred sea lions during the pupping and mating season in June. On this rock shelf, no more than two acres in area, ninety per cent of all the Steller pups were born. When a vicious storm swept in—especially if it coincided with the highest tides for the month—this was the only dry, reasonably level place accessible to sea lions on Rookery Islet. Even so, each heavy storm took its toll of the newborn, often not so much by its own violence as by the chaos and crowding it induced as animals were forced from outlying rocks into the pupping area.

Heavy storms usually brought a temporary breakdown of the Steller communities. On the seaward side of Rookery Islet, such a storm would send the waves crashing high in the air. High tide could give the water fifteen feet more reach. With the first spray whipping over the mating areas, the cows moved restlessly. When the tide reached its full height, the seas would crash over the sea lions. After taking a few waves, most cows dived off into the churning surf—over the protest of the bull who tried to keep them—and swam to the leeward side of the islet. The harem bulls would hold their territory against the seas until literally swept off. In all likelihood, they would have to fight for the same position when the storm receded.

Mothers with newborn worried over their youngsters. The pups —unable to climb the higher boulders and rock shelves to safety—would try to crawl under the shelter of house-sized boulders, but the seas washed in behind them. It was then the mothers picked up their young by their furry hides, as a cat does her kittens, and carried them to higher ground. This carrying of pups, never recorded



The ears of the hair seals are internal, and only the aural openings are visible.



Hair seals have furred flippers, and claws appear at tips of the phalanges.

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his bulging shoulder and neck muscles as he throws his head back in warning.

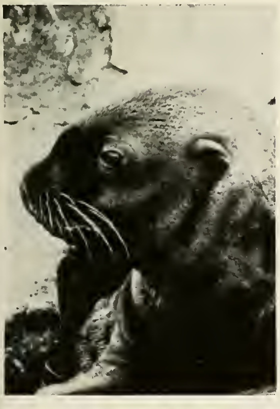
Growling and tossing head, the sea lion discourages author's advance. If beast had charged, he could have been outmaneuvered on the dry, smooth rock.

among the hair seals, gives the young sea lions a better survival chance in unusually bad weather. Yet the great press of sea lions in the pupping area during a storm—with the bulls lunging heedlessly as they tried to maintain something of their harems in the chaos—meant that some pups were trampled to death in spite of the mothers' best defenses. When such a storm ends, the animals go into the sea to feed: upon returning, they again populate the storm-cleared seaward rocks.

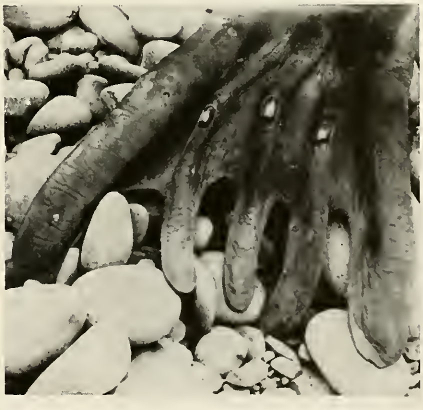
After the June-born Steller pups gain enough strength to flap about on the rocks, they tend to gather in groups of their own in the highest, flattest locations. In their second week, they will take to the sea to avoid capture by a boat. Seeing the pups swimming for the first time, it is plain that the aquatic grace of the older animals is learned. The pups beat the water with their front flippers, in an effort to keep their heads as high out of water as possible. If frightened into moving too far out to sea, it is likely that they would soon exhaust their small supply of energy and drown, yet we never saw the mothers make an attempt to assist them in the water. By their third and fourth weeks, however, the young pups will submerge to escape capture and can swim about twenty feet underwater before they must surface for breath.

A swimming sea lion does not exhale underwater: both exhaling and inhaling are done during a brief thrust of the head above the surface. When cruising leisurely, they may respire more than once before submerging again. They normally stay submerged for no more than five minutes.

In the water, the Steller's great flipper area results more in excellent maneuverability than in sheer speed. In leisurely swimming, the sea lion gives a mighty breaststroke sweep of his front flippers and glides swiftly, steering and maintaining moderate speed by sculling the flippers close to his sides. At panic speeds, the front flippers are folded for stabilization



The sea lions have external ears, which remain small, are virtually vestigial.



Claws of Steller tip phalanges, but hair-covered cartilage extends beyond.

Alaska's Department of Fish and Game made daily counts of the sexes in the harem areas, and regular observations of the behavior patterns of Steller sea lions within their own domain. Russia and Canada are also conducting studies.

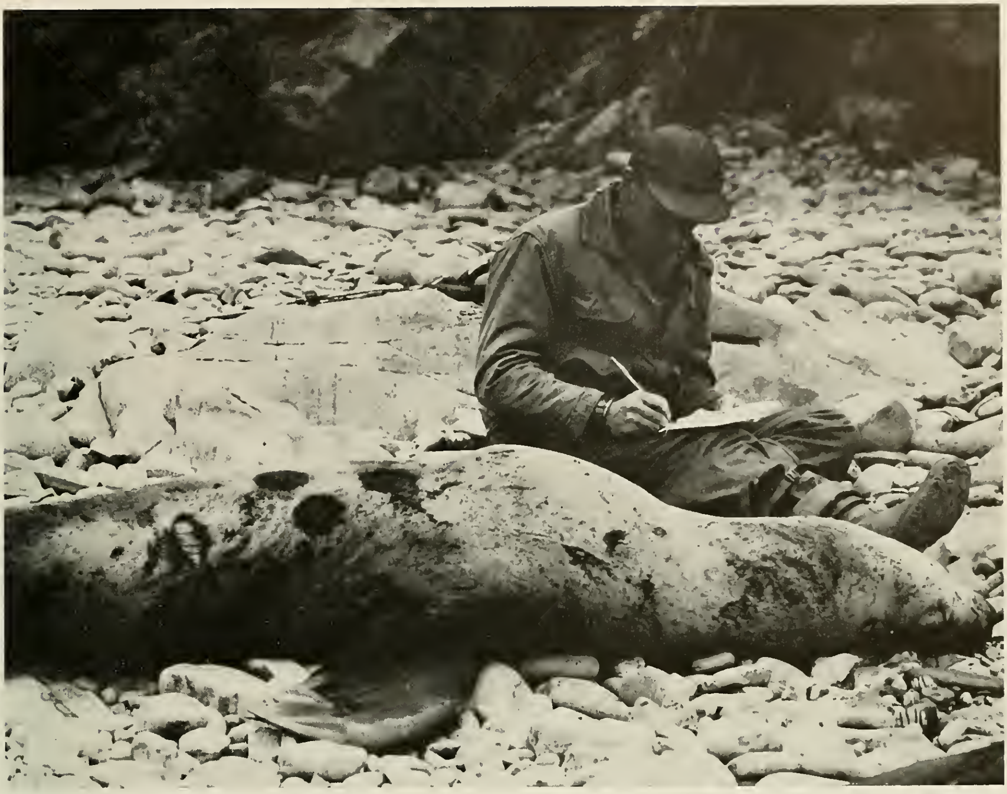
Newborn's malformed nose and mouth doom him to lose battle for survival.

only—the long hind flippers driving the sea lion as it undulates the rear portion of its body.

I saw maximum escape effort demonstrated best by a bull I challenged on our own boat-landing beach. While I was seated there, a bull (it must have been a newcomer) surfaced and then sat in the surf. Then, with much caution and looking about, he hauled out completely onto the beach. I remained quietly on my rock and his eyes did not separate me from the scenery. After we had both rested together for ten minutes. I charged him at my top speed, expecting him to be panicked by the sight of a creature arising from nowhere and hurtling down the beach incline at "unsealionlike" speed. Even so, I admit I slowed down during the last fifteen feet. He had not moved at all, and I was not sure but that I might have to reverse and move back at the same speed with which I had descended—even faster, perhaps. But with a scant ten feet of distance between us, my bluff proved successful and he turned and hurled himself back toward the surf, while I almost trod on his hind flippers.

In the shallow, boulder-strewn water, he could not risk swift underwater flight. Instead, he leaped over the surface with great butterfly strokes from his front flippers, while his hind flippers beat the water behind him to foam. Once in deeper water he was off under the surface in curving, evasive, speedy flight. Sensing there was no pursuit, he surfaced to survey the beach, snort, and continue slowly on his way.

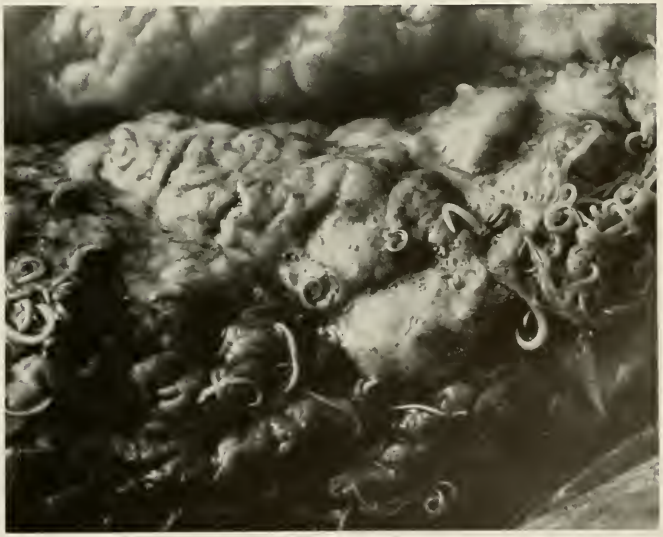
Stellers are extremely vocal, perhaps because they are extremely gregarious. The Steller's "roar" (which can justifiably be so called when heard as the unified voice of hundreds of animals) is actually a very low-pitched bellow. The pitch of the call varies



Fungus skin infections that plague the Steller sea lion are nearly circular, slightly raised, and purple in color when wet. In addition to his bodily ailments, the sea lion must also compete with the encroachments of civilization.

with the size of the animal. The newborn yell "A-a-a-a" for their mothers; the yearlings, "Ah-ah-ah"; the mothers answer "Oh-o-o-o"; and the bulls say "Uh-uh-uh!" At a rookery, all these calls go on continuously, sometimes more loudly than others. There is also a rare, bugling call, the significance of which we were unable to determine. It was always given by a cow on the rocks in an undisturbed group; other sea lions showed no reaction to it.

For all their sameness, the Stellers can get a lot of expression in their calls, varying them in frequency and intensity. One call always embarrassed me. At intervals, we weighed marked pups to determine the weight gains with growth. When we arrived to do this, the adult sea lions left their rocks but did not abandon the young entirely; they remained in the water, just offshore, watching. As I caught a squirming pup by the hind flippers and put it into a stout net to be



Parasites, which include roundworms, here shown in a stomach lining, infest young sea lions with their first bite of fish. Tapeworms are also a scourge.

weighed, the dispossessed mothers and the harem bulls reared high as they could out of the water. The mothers craned their necks, as if asking . . . what were we doing with that pup? . . . was it hers? And then, from all the open mouths, would come a long, sustained moan. It always sounded to me as if they had all cried, "Sha-a-a-ame!" One could not help looking around at them nervously, wishing to reassure them.

Today, the larger Steller rookeries are found where the sea is unfriendly to fishermen. In thinly populated Alaska, a good number of locations so qualify. In the largest Steller rookery in the world—the Barren Islands—photographic surveys of population run as high as 15,000 animals. There are smaller Steller rookeries on Bogoslof, Amak, and other islands of the Aleutians, and many tiny groups (under twenty animals) scattered on small rock-tables along the northern coast. Stellers also congregate on the Pribilof Islands, but at different shore locations than those dominated by their more famous cousins, the Pribilof fur seals. Only one mainland rookery exists in North America, about two hundred animals near Florence, Oregon.

Anthropomorphically speaking, the Steller sea lions' policy regarding the other inhabitants of its environment could be phrased "peace, brothers; we have enough fighting among ourselves." The Steller will come ashore among fur seals without looking for trouble, while hair seals are allowed to share the rocks off Stellar rookeries with the harem bulls and cows. Killer whales are big enough to cause a solitary sea lion some worry, but the killers avoid the rookery areas. Stellers have been observed initiating group forays toward distant killer whales, but the killer whales showed no desire to meet such irate groups.

Sea lions and fur seals belong to the family *Otariidae*, so named because of their external ears. Well-developed flippers, on which they are able to walk, are another distinguishing feature of the family. The seal family proper, *Phocidae*, have no visible ears, the flippers are not well developed, and they move by humping in caterpillar-like fashion.

In all, it may well be said that the Steller has adjusted perfectly to his niche — except, as we have seen, for man. The studies in progress, today, may help convince fishermen and legislators alike that the sea lion is not a significant predator on commercial fish. Although conservation measures are often slow to come in virgin country, every year, a more enlightened approach is being accepted. If there is any frontier left, the Steller sea lions deserve a place on it. Only along the most savage parts of ice-free coast and ocean can they congregate and hold their population numbers. And that is where the Steller appears at his best: on the rocks above the crashing surf, the air heavy with the cries of thousands of his kind—above him, bright wings of gulls, and the thick, sundown flight of puffins from their burrows. Then the Stellers sit above the living sea, well able to take care of themselves—if they are left alone.

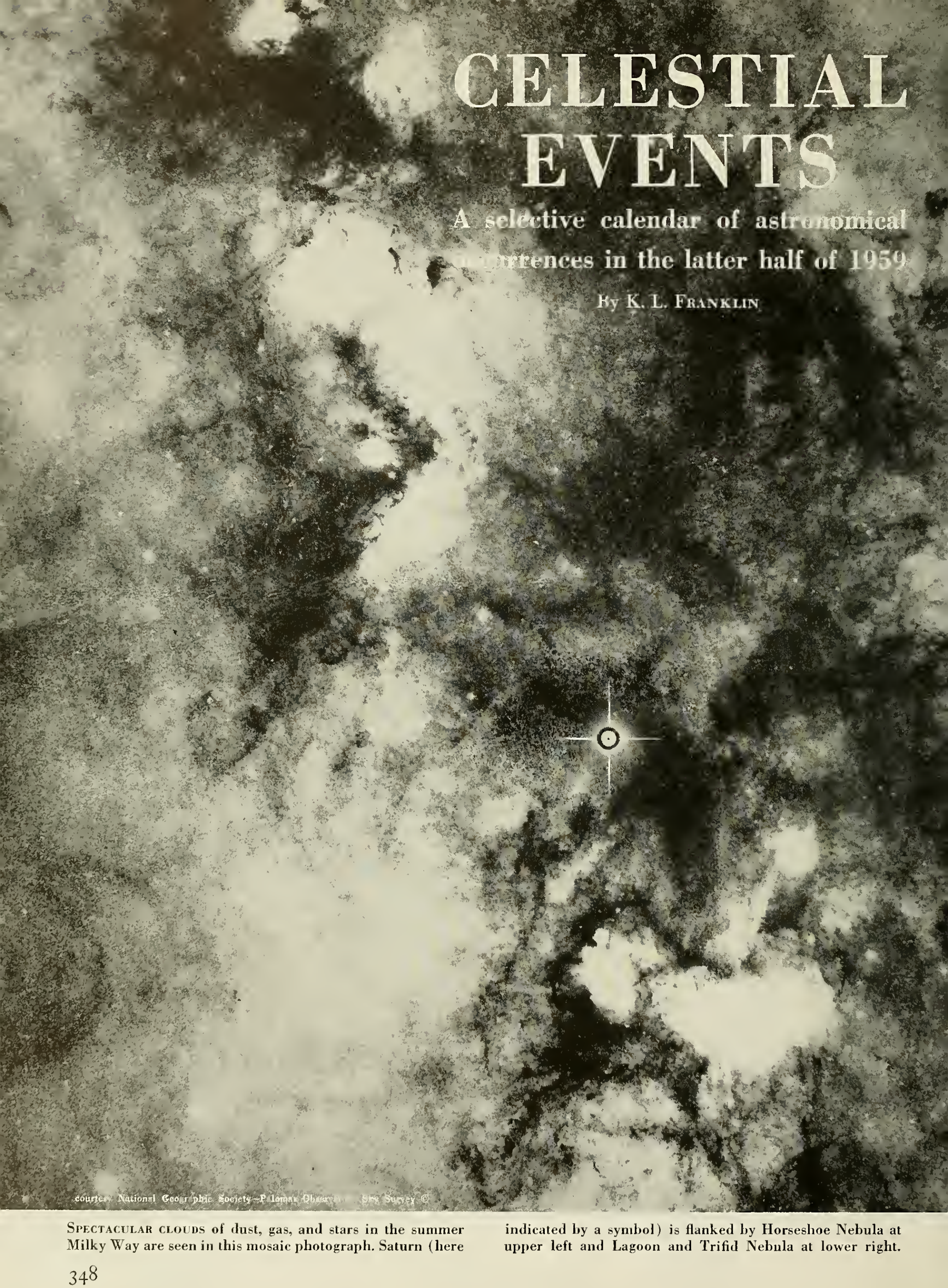
Protesting cows and bulls gather close to edge of rookery as scientists on the shore catch the pups and weigh them.

Threats from man and storm temporarily over, Steller on his rock, *right*, looks out to sea and scratches contentedly.

CELESTIAL EVENTS

A selective calendar of astronomical occurrences in the latter half of 1959

By K. L. Franklin



courtesy National Geographic Society—Palomar Observatory Sky Survey ©

Spectacular clouds of dust, gas, and stars in the summer Milky Way are seen in this mosaic photograph. Saturn (here indicated by a symbol) is flanked by Horseshoe Nebula at upper left and Lagoon and Trifid Nebula at lower right.

JULY

July 5: This morning the earth is at the *aphelion* point of its orbit, the greatest distance (94.5 million miles) from the sun this year.

July 7: Shortly after 9:00 A.M., EDT, the planet Venus will pass directly in front of the brightest star in Leo, Regulus. This is a very unusual event, but it will be very difficult to observe. One must use a telescope in order to discern Regulus, because the occultation, lasting less than ten minutes, will take place in daylight and quite low in the eastern sky for those watchers on the East Coast.

July 8: Look in the west near the horizon just after sunset. The bright object you may find is fleeting Mercury, at its greatest easterly distance from the sun this summer.

July 8-15: During this approximate time, every major object of the solar system will be above the horizon just before sunset. This includes the sun and crescent moon, each of the planets (except the earth, which *is* the horizon), and the four asteroids—Ceres, Juno, Pallas, and Vesta. These minor planets and Uranus, Neptune, and Pluto can be observed only with the aid of suitable telescopes.

July 9: Venus and the crescent moon will be in close company near Regulus in the western sky this evening.

July 14: The moon will approach Jupiter to within about four lunar diameters by midnight.

July 20-August 7: Celestial interest on these evenings will be sparked by the appearance of meteors belonging to the stream seeming to radiate from the star Delta Aquarii. An observer may be able to count as many as twenty per hour on the night of July 29 when the Delta Aquarids reach their peak.

July 26: Venus, 42 million miles away, will be its brightest as an evening object.

AUGUST

August 5: Mercury, 55 million miles away, is at *inferior conjunction*—that is, between the earth and the sun.

August 10: Venus and Mars are nearly 7° apart tonight in the constellation of Leo.

August 10-15: The meteor shower called the Perseids will reach a maximum of about fifty per hour on the night of the twelfth.

August 23: Mercury may be found in the east just before dawn, but look sharp!

August 26: The moon is at last quarter at 4:03 A.M., EDT, and is at *apogee* at 2:00 A.M., EDT—251,400 miles away. This combination results in a minimum range between high and low tides on the night of August 25/26.

SEPTEMBER

September 1: Venus is between the earth and the sun (at *inferior conjunction*), 27 million miles from the earth. Venus comes closer to the earth than any other planet in the solar system, the closest such approach coming whenever an *inferior conjunction* occurs in January.

September 17: Mercury is now at *superior conjunction*, 128 million miles away, on the other side of the sun.

September 22: About midnight tonight, the moon passes in front of the brightest star in Taurus, Aldebaran. This spectacular occultation will not be seen from the West Coast. Watch especially for the abrupt emergence of the star.

Dr. Franklin, of The American Museum-Hayden Planetarium, prepares this summary each six months.

September 23: The sun crosses the equator at 3:09 P.M., EDT, into the Southern Hemisphere. *Autumn* begins.

OCTOBER

October 2: Eastern Massachusetts, just north of Boston, will receive the shadow of the moon this morning, as the sun rises during a total eclipse. The entire eastern seaboard and part of the Great Lakes can view some partial eclipse phenomenon at sunrise. The path of the moon's shadow will sweep across the Atlantic to the Canary Islands, across the Sahara Desert, and will end in the Indian Ocean off the coast of Somalia.

October 8: Venus is at its brightest this year in the morning sky. It is 40 million miles from the earth.

October 9/10: Ardent meteor observers, and anyone else interested in a spectacular meteor display, should begin watching before midnight and maintain the vigil until sunrise. This date in 1933 and 1946 saw the occurrence of the Giacobinid shower—several thousand meteors per hour. The earth crosses the orbit of Comet Giacobini-Zinner just twenty-two days before the comet, probably not visible to the naked eye, crosses the earth's orbit. It is not certain if a shower will actually be seen in the Western Hemisphere, but if it occurs, the sky will be very busy for little more than one hour. Do not fall asleep!

October 20: The moon occults Aldebaran shortly after 10:00 A.M., EDT, but is best observed from the West Coast.

October 20-22: The Orionid meteor shower reaches a peak of about twenty-five per hour in the morning hours of October 21.

October 25: Daylight Saving Time ends for many areas of the country. 2:00 A.M., EDT, becomes 1:00 A.M., EST.

October 28: Venus and the moon will be very close in the sky at 8:40 A.M., EST. This is still dark for much of the country, and is well worth attempting to see. Some observers in the Southern Hemisphere may be able to see Venus occulted by the moon.

NOVEMBER

November 24: Mercury is 63 million miles from the earth at *inferior conjunction*—between the earth and the sun.

November 30: New moon occurs at *perigee* (221,600 miles from the earth), a combination which will produce a high range between high and low tides for about a day.

DECEMBER

December 11-15: The Geminid meteor shower will reach its maximum of about fifty per hour for a single observer on the evening of the thirteenth.

December 13: The western United States can see an occultation of Aldebaran about sunset or shortly after.

December 22: The sun is at its most southerly point in the sky at 9:35 A.M., EST. *Winter* begins.

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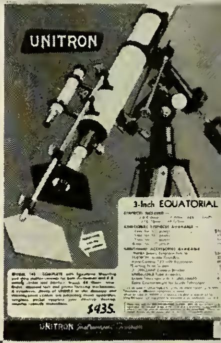
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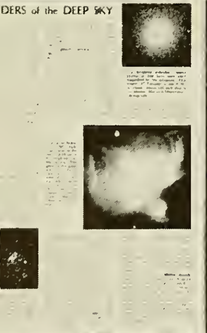
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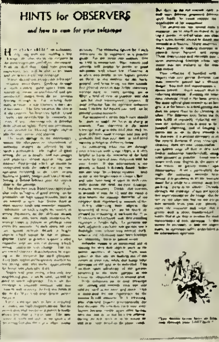
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SKY REPORTER

June and July offer a dramatic picture in the Summer Triangle area

By Henry M. Neely

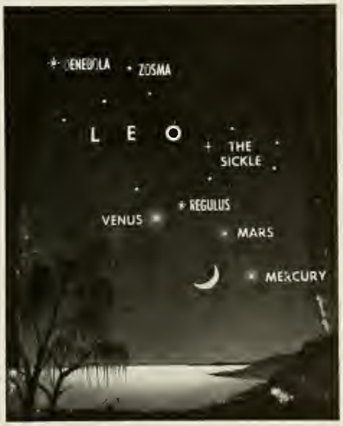
THE NIGHTS OF JUNE AND JULY bring into good position for viewing one of the most dramatic areas to be found in the entire sky. This is the area in and around the familiar figure known as the Summer Triangle—and, particularly, the part within the boundaries of the constellation Cygnus. This area is seen on the June map (page 352) above the horizon, between east and northeast, and on the July map (page 353) directly above the east, at the indicated hours.

To the naked eye observer, free from the distractions of artificial lights and moonlight, the zone is immersed in one of the most striking parts of the Milky Way. Here, the luminous band seems to divide into two branches, separated by a great dark streak, which observers of old named the Great Rift, because they believed it to be a vast opening in the shining clouds—through which they were looking out into the supposed darkness of infinite space.

Today, astronomers know that, instead of being void, the Great Rift is itself a gigantic cloud of tenuous gas and dust, so vast in its dimensions that it totally obscures the light from the unknown millions of stars that lie beyond it. Throughout this area, photographs made by the great observatories show streaks and patches of cloud; some dark, others made luminous by the radiation from the myriad stars imbedded in them or quite close to them.

Among the most striking of these features are the North America nebula and the bright streamers of the Filimentary (or Network) nebula, which suggest the tattered outline of an immense circle of material—possibly hurled outward many millions of years ago by a supernova.

From Cygnus, too, come some of the strongest signals known to the specialists who are working in the new science of radio astronomy. There is now a widely accepted theory that these bursts of radio noise come from two great galaxies in the process of colliding with each other—at a distance from us that is so vast as to be almost inconceivable.



Invisible in June, Mercury reappears on July 8, to be seen on western horizon.

The name Cygnus means a swan and the figure of the imaginary bird is easy to trace on the maps. The star Deneb is the tail; Sadr is the body and the long neck stretches out to Albireo, which represents the beak. The outspread wings are formed by the two bending lines of stars branching out on both sides from Sadr. A part of this figure is even better known as the Northern Cross. Deneb, Sadr, and Albireo form the long arm of the cross, while the short arm runs from Sadr to the nearest bright star on either side of it. Albireo is one of the favorite double stars for owners of small telescopes. One of the pair is gold; the other, violet. They present one of the best color contrasts to be found in the sky and they are easily "split," even with an instrument of only moderate power.

In some ways, one of the least conspicuous stars in Cygnus is the most exciting. This star has no name but has been given the number "61" in star catalogues.

This was the first star the distance of which was successfully found by the surveyors' method of triangulation. The feat was accomplished by Bessel in 1838. This star—61 Cygni—is so distant that its light—speeding at some eleven million miles each minute—requires nearly eleven years to reach us. Yet there are only fourteen stars closer to our solar system than that.

But it has remained for contemporary astronomy to lend the greatest excitement to 61 Cygni. Not long after Bessel's work, it was discovered that 61 Cygni is actually a system of two stars—revolving around a common center of gravity. Long observation revealed irregularities in the motion of the brighter star and study of these irregularities indicated that this star was, itself, a double system. Then, as more evidence was accumulated, astronomers were faced with a startling question—was this double system another double star or was it a star and a planet?

The unseen companion apparently is only about one-sixtieth of the mass of our sun—or about sixteen times as massive as Jupiter—not nearly large enough to be considered of stellar dimensions. Consequently, many experts wonder whether, in 61 Cygni, we see another example of a solar system like our own—not identical, of course, but dynamically similar to our sun and its family of planets. This is entirely speculative at present and a definite answer must await the development of instruments and techniques of observation not now available.

Coming closer to home than the stars, the months of June and July will offer many interesting evenings to observers who like to study the motions of the planets.

Mercury will not be seen in June but, on July 8, when it is farthest east of the sun, watchers with unobstructed western horizons may see it together with the moon, Mars, and Venus as the evening dusk deepens (illustration, *left*).

This will be an excellent "elongation" of Mercury for observers in the south, but not so good for those above latitude 40° North, with late summer sunsets.

Jupiter and Saturn, on both star maps, will be conspicuous objects in our night sky until autumn.

With the coming of June and July, thousands of enthusiastic amateurs who observe and record meteors ("shooting stars") begin their busiest season of the year, leading into the spectacular displays of August. From July onward a persistent observer will see from ten to fifteen meteors per hour after midnight and will see twice as many then as before that hour.

The nights from June 2 to 17 bring us a shower radiating from near the bright star Antares, in Scorpius, with maximum due about June 14. The moon will set early enough to make conditions favorable. About 1:00 a.m., Antares will be seen almost due south (as on the July map).

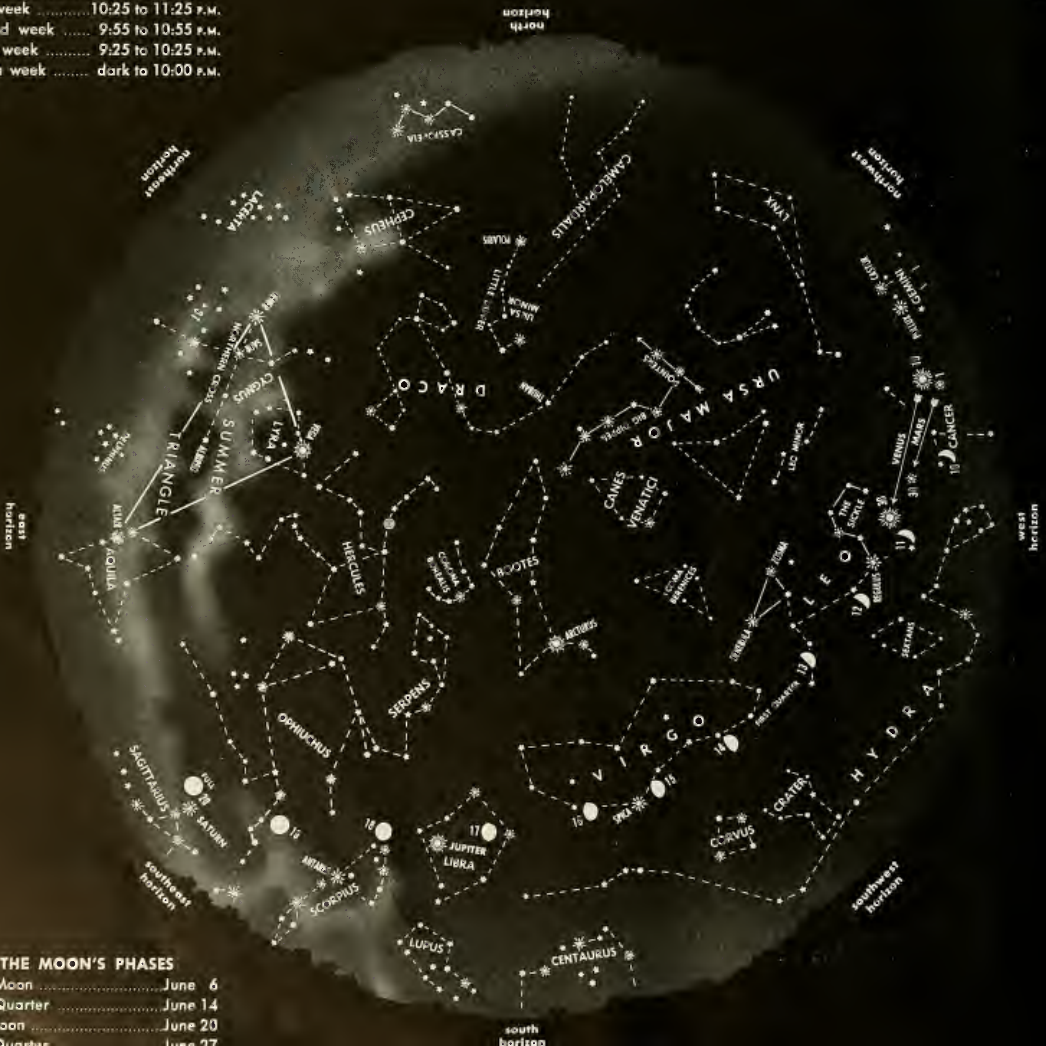
From June 27 to 30, meteors known as the Iota Draconids are due, radiating from near the star Thuban, in Draco, not far from the Big Dipper. The last quarter-moon will not rise until about 1:00 a.m. and there is a chance of seeing an average of twelve an hour until the moon is well up in the late night sky.

Throughout July, few nights are without "shooting stars." This year, however, the July moon will not cooperate. The first of the famous Perseids may be seen after July 15, as the moon sets before dawn, but the full moon—on July 20—will interfere with predawn observing until the end of the month. However, the Perseids continue well into August, as do the Alpha Capricornids (which come from near the star Algiedi, in Capricornus)—seen on the roll-around map for July above the southeast horizon.

Another famous shower, beginning July 22, comes from Aquarius, shown just rising near the east on the July map. This is usually a fine display but, this month, the moon will be too near until after July 27, when the radiant will be well up over the southeast before moonrise.

JUNE TIMETABLE

First week	10:25 to 11:25 P.M.
Second week	9:55 to 10:55 P.M.
Third week	9:25 to 10:25 P.M.
Fourth week	dark to 10:00 P.M.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POLARIS
LITTLE DIPPER
URSA MINOR
DENEB
NORTHERN CROSS
CYGNUS
D R A C O
THUBAN
POINTERS
BIG DIPPER
U R S A M A J O R
CASTOR
POLLUX
GEMINI
DELPHINUS
LYRA
VEGA
SUMMER
TRIANGLE
ALTAIR
AQUILA
HERCULES
CORONA BOREALIS
BOOTES
CANES VENATICI
LEO MINOR
VENUS
MARS
CANCER
THE SICKLE
REGULUS
ZOSMA
DENEBOLA
L E O
COMA BERENICES
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SEXTANS
SERPENS
OPHIUCHUS
FIRST QUARTER
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THE MOON'S PHASES

New Moon	June 6
First Quarter	June 14
Full Moon	June 20
Last Quarter	June 27

BEGINNERS in star identification will find the moon helpful in using the maps. Find the moon for the chosen date, "roll" the map to bring that moon vertically above the horizon and the relative positions of the brighter stars can then be seen and the map compared to the sky.

It is always interesting to see the moon quite close to a brilliant star or planet.

On the June map, the moon for June 11 is just under bright REGULUS, and the figure of the Sickle in LEO.

On June 15, identify first magnitude SPICA to the left of the moon: on June 16, SPICA will be to the moon's right. Another well-known star, brilliant ARCTURUS, can readily be identified by following straight up above SPICA.

On June 17, great JUPITER will be to the left of the moon; on July 18, JUPITER will be to the right. ANTARES, in SCORPIUS, will be found below JUPITER.

The full moon of June 20 will blot out all of the stars near it but keen eyes may discern SATURN just under it.

As dusk deepens on the evening of July 8, we get the picture shown in the illustration on page 351.

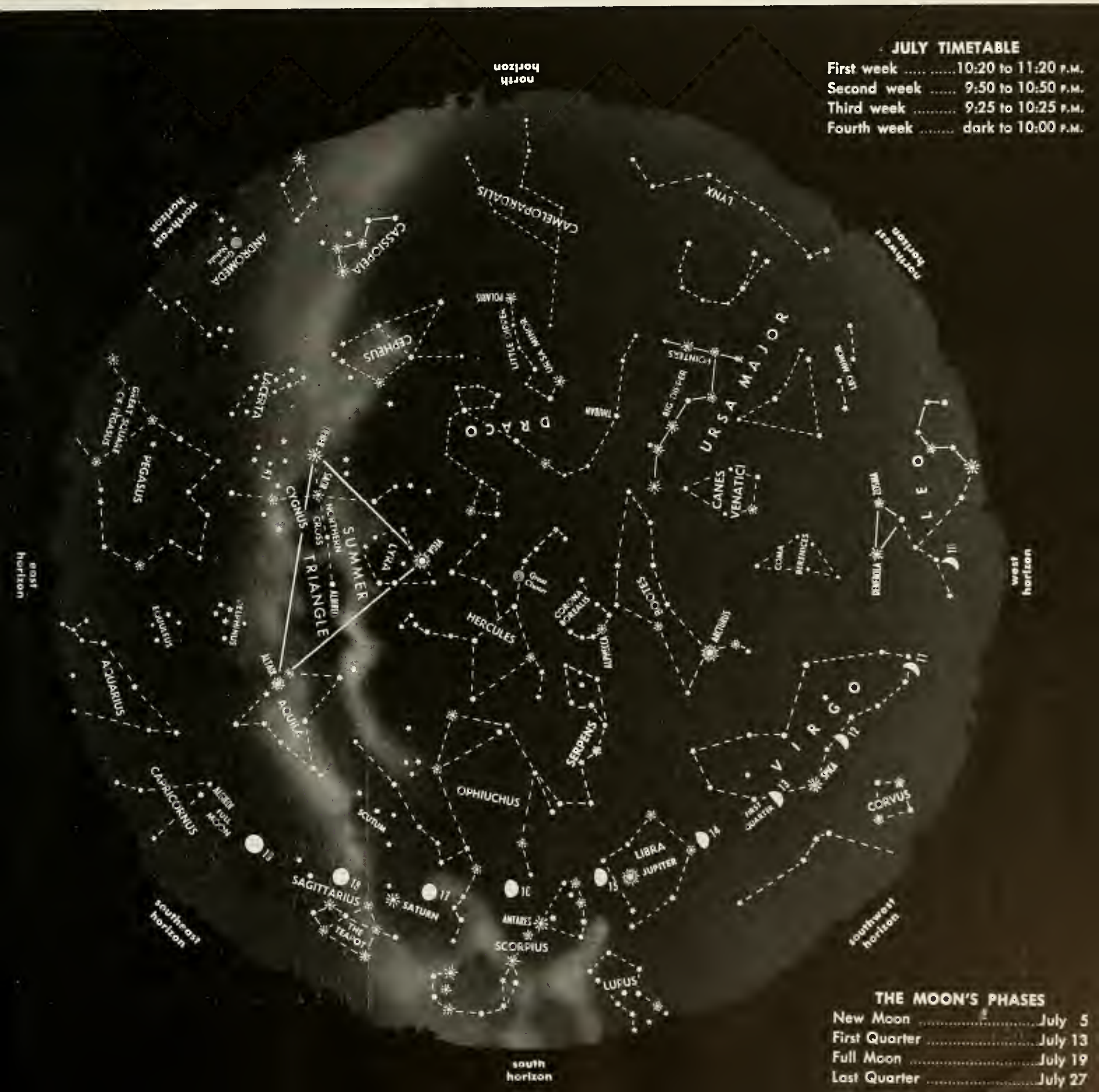
Readers who missed the June moon as a star pointer may make use of the July moon in the same fashion.

Bright SPICA can be found near the moon on July 12 and 13, with brilliant ARCTURUS almost straight above it.

Again the moon will introduce readers to great JUPITER on July 14 and 15, with first magnitude ANTARES below.

On July 17 and 18, SATURN can easily be found—with the familiar figure of the Teapot, in SAGITTARIUS, below.

MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this regular feature for NATURAL HISTORY.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POINTERS
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BIG DIPPER
LEO MINOR
LACERTA
GREAT SQUARE OF PEGASUS
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THUBAN
CANES VENATICI
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SATURN
THE TEAPOT
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JULY TIMETABLE

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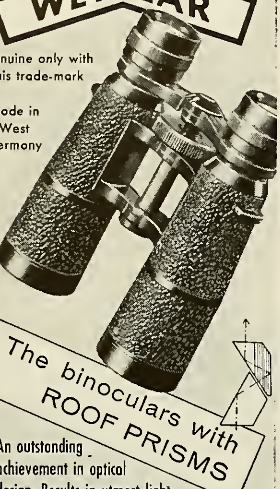
THE MOON'S PHASES

New Moon	July 5
First Quarter	July 13
Full Moon	July 19
Last Quarter	July 27



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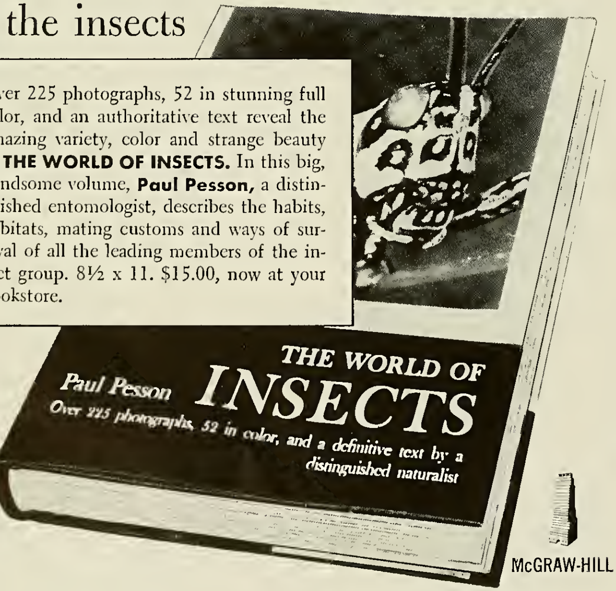
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McGRAW-HILL

REVIEWS *(Continued from page 300)*

These two books, incidentally, are typical of this publisher, who has pioneered in paperbound reprints of scientific and technical classics that students could otherwise find only on the shelves of a good library.

Another kind of classic, one of a handful to span the gap between scientific writing and pure literature, is *Kamongo or The Lungfish and the Padre*, by Homer W. Smith (Viking, 95¢). The similarities and divergencies of science and religion have never been more tellingly discussed than in this long, Socratic dialogue, held in the Conradian setting of a ship in the tropics.

The Immense Journey, by Loren Eiseley (Random House, 95¢), is also philosophical in tone—a naturalist's musings about the long road of evolution that the animal kingdom has traveled. Eiseley's essays do not have the sweep or finish of *Kamongo*, but are full of interesting ideas and insights.

There are plenty of ideas, too, in *The Social Life of Animals*, by W. C. Allee (Beacon, $1.45). Before his death, this veteran biologist reviewed in detail experiments (by himself and others) that went to prove that community activity and co-operation are a far more "natural" way of life in most species than the dog-eat-dog concept of the early evolutionists. He carried his inescapable conclusion into human affairs with a reasoned and experimentally documented plea for international co-operation.

The History of Nature, by C. F. von Weizsacker (Univ. of Chicago, $1.25), is an ambitious attempt to relate man to the universe by tracing his and the universe's history, and, again — as in *Kamongo* — to achieve some sort of workable synthesis between the scientific and the religious attitude. The author writes as a physicist and as a Christian, and if his synthesis may not seem entirely successful, he fails only where none of the greatest philosophers has succeeded and in the meanwhile does a memorable job of physically pinpointing the position of mankind on the vast stage of existence.

Scientific speculation of another kind is represented by two very different books on the same subject—the origin of the people of Polynesia. *Kon-Tiki*, by Thor Heyerdahl (Pocket Books, 35¢), is the familiar, muscular best seller, whose author drifted a balsa raft westward from Peru to prove that this was a feasible route of migration. Whatever it proves, it is grand reading.

In *Vikings of the Pacific* (Univ. of Chicago, $1.95), the late Peter H. Buck marshaled an impressive dossier of evidence from tradition and folklore to prove that the ancient Polynesians came from Asia and, voyaging eastward in

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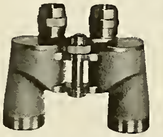

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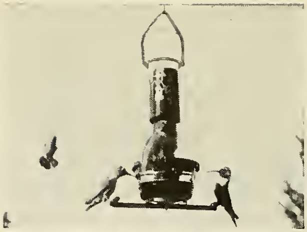

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their frail canoes, eventually peopled most of the widely separated island groups of the Pacific. Sir Peter wove songs and myths and information from other sources into a narrative quite as exciting in its own way as the Kon-Tiki voyage — and a good deal closer to probability than Heyerdahl's hypothesis.

MOST people who enjoy the ceaseless play of light and color in sky, sea, and landscape know and appreciate what they see without more than a very general idea about why they see it. *The Nature of Light and Color in the Open Air*, by M. Minnaert (DOVER, $1.95), is a Dutch physicist's account of the causes of every sort of visual phenomenon from sun halos and variations in sky color to mirages and the phosphorescence of fungi. To anyone who has ever tried to find a satisfactory printed explanation for some of these effects, this is a uniquely valuable reference book—and one that can be read simply for the pleasure of sharpening one's own awareness of light.

In closing, two quarterly "magazines" in paperback form are of particular interest to amateurs of natural science. *Science News* (PENGUIN, 65¢) covers all of the sciences and always has articles on the biological and earth sciences; *New Biology* (PENGUIN, 65¢) is, as its name indicates, entirely devoted to biology. All articles in both publications are written by authorities and the standards of clarity and interest are very high.

The check list that follows is neither exhaustive nor, strictly, critical. It has been prepared chiefly to show the extraordinary range of paperbacks now available in the fields covered by NATURAL HISTORY. A visit to one of the "paperbacks-only" bookstores, which have sprung up in many cities, or a look through the Bowker catalogue, will uncover many worthwhile titles not listed here — and new ones are being added weekly.

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THE WORLD OF COPERNICUS: Angus Armitage; *New American Library of World Literature, 50¢*

PLATO'S COSMOLOGY: Francis M. Cornford; *Liberal Arts Press, Inc., $1.75*

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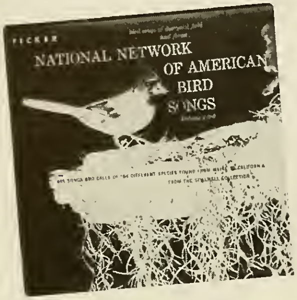

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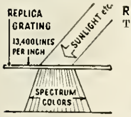

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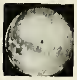

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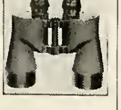

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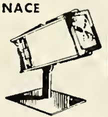

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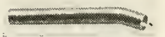

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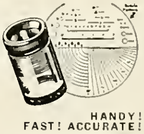

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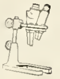

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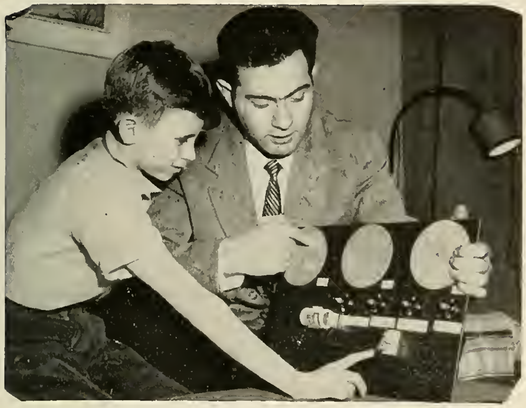

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Vol. LXVIII

NATURAL HISTORY

No. 7

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August–September 1959

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To the red-shirted young man on the cover, every day at the shore is a journey of discovery. At low tide he can explore among the weeds and damp rocks in search of barnacles and crabs or examine the jellyfish that lie invitingly on the mud flats. Like the tides, themselves, the young are seldom still. In August, as the specter of winter's confinement begins to loom over the long summer days, there comes a particular urge to *look* (and perhaps to learn) every moment of every hour. John Hay, whose notes on this subject begin on page 370, is President of The Cape Cod Junior Museum, and has a strong sympathy both for the sea and for the children who explore its shores. Mrs. Strong's pictures speak for themselves — of summer and of the young investigators to whom this season of the year particularly belongs.

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NEW DIRECTOR APPOINTED

James A. Oliver

THE appointment of Dr. James A. Oliver as Director of The American Museum of Natural History was announced on June 3 by Alexander M. White, President of the Museum. Dr. Oliver, at present the Director of the New York Zoological Park, will assume his new post on September 15. 1959.

Upon receiving his Ph.D. from the University of Michigan in 1942. Dr. Oliver, who is a specialist in herpetology, joined the staff of The American Museum as an assistant curator in the Department of Amphibians and Reptiles. Following wartime leave. during which he served with the U. S. Navy. Dr. Oliver returned to the Museum staff in 1947 as an associate curator. In 1948. he went to the University of Florida as Assistant Professor in the Department of Biology.

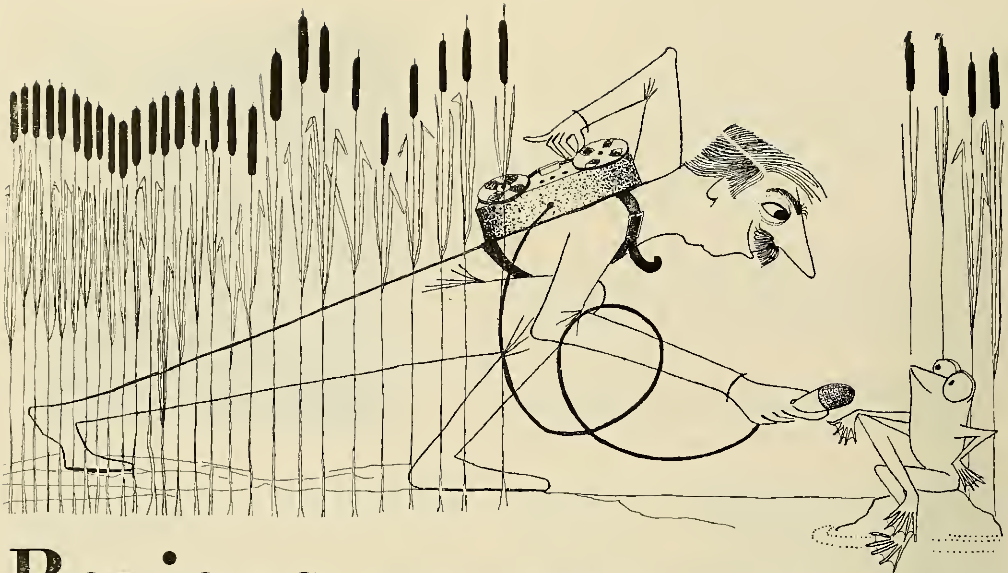
Dr. Oliver joined the New York Zoological Society in 1951 as Curator of Reptiles. He became Assistant Director of the New York Zoological Park (more familiarly known as the Bronx Zoo) in April, 1958, and Director in June of that year. His research investigations there include the first detailed observations of the breeding of king cobras in captivity, and of the courtship of this species, which had never before bred in confinement. In addition to his scientific publications, Dr. Oliver's popular writings include two books, *The Natural History of North American Amphibians and Reptiles*, and *Snakes in Fact and Fiction.*

Albert E. Parr

THIS new appointment will permit the first implementation of a policy recently established by the Museum's Board of Trustees, whereby a director may relinquish his post after fifteen years of service to assume the newly established position of Senior Scientist until the time of his retirement. Thus, the present Director, Dr. Albert E. Parr. will be able this autumn to resume those research activities that he gave up to a large degree upon assuming that post more than a decade ago.

Dr. Parr served with the Bergen Museum and the Norwegian Bureau of Fisheries before leaving Norway for the United States in 1926. When the Bingham Oceanographic Collection. of which he had become Curator, was transferred to Yale University's Peabody Museum of Natural History, Dr. Parr joined the Peabody staff as an assistant curator of zoology. While at Yale, he served successively as Professor of Oceanography. Director of Oceanic Expeditions. and Director of Marine Research. He became Director of the Peabody Museum in 1938. where he remained until 1942. when he accepted the directorship of The American Museum of Natural History.

The author of many studies in marine biology. Dr. Parr has also published a number of articles on museum administration. In his laboratory at the Museum. he has found time to work on classifying a group of deep sea fish. Alepocephalids. A past president of the American Association of Museums. Dr. Parr has served as a member of the United States National Commission for UNESCO. and was Chairman of the 1958 International Design Conference.



Reviews

RECORDING THE SOUNDS OF NATURE

Reviewed by Charles M. Bogert

MAN IS A NOISY ANIMAL. Purposely or otherwise, he has succeeded in making more and louder, if not always better, sounds than any of his predecessors or contemporaries. Furthermore, he contrives ways to preserve and disseminate almost every sound he makes or hears. Eighty-three years ago, Edison could scarcely have foreseen the consequences when he rigged a needle to a diaphragm, wrapped some foil around a cylinder, and demonstrated that sounds need not be born only to die away. Once the phonograph was perfected, man set out to store up enough sounds to last him until doomsday.

The evolution of the phonograph record, from cylinders of foil, wax, and celluloid to the various modifications of the disc, is only part of this story. When radio came into the picture, loudspeakers — accompanied by microphones and amplifiers—replaced simple horns. When electronic equipment superseded the relatively simple mechanical gadgetry of the recording studios, many of us thought perfection had arrived. But wire recorders were still to come, with tape not far in the future. Before we could find space in our attics to store additional outmoded phonographic equipment, hi-fi was upon us. And stereophonic recording remained in the offing as a final sales gimmick. Beyond this, at the moment, there is nothing — nothing, that is, but sound. Today the auditory barrage descending on us is unlike anything man has ever before experienced.

The time, thought, and ingenuity spent on improving our techniques for recording and reproducing sound are testimony to the importance we attach to preserving the sounds we ourselves make. We have devoted much less attention to sounds made by other animals—but for technical reasons, rather than because of any lack of interest. Concerted effort to understand the biological significance of the frog's croaks, the bird's song, or the bat's high-pitched squeaks necessarily awaited the advent of electronics. Few of these animals could be counted on to perform in the studio, much less direct their vocalizations into the horn required for early recordings. Instead, the recording equipment must be taken to the field, where animals call under natural conditions, and this was an almost impossible task until the biologist was provided with an instrument he could carry—a battery-operated, tape recorder. Today, with relative ease, he can record and reproduce whistles, growls, grunts, thumps, drones, hisses, and cries—the indescribable, if not infinite, variety of sounds made by animals, regardless of their environment. The "silent depths of the sea," for one example, have proven to be an aquatic bedlam of snapping shrimps, drumming and croaking fishes, and squeaking sea mammals.

Dr. Peter Paul Kellogg, who started recording animal sounds at Cornell University over thirty years ago, looks back with not even a tinge of nostalgia to 1935—when he and his colleagues required a wagon and four mules to lug nearly a ton of equipment into the swamps for a recording of the ivory-billed woodpecker. Today, Kellogg could obtain an even better recording of the bird by sneaking quietly into the swamp with thirty pounds of equipment, including a supply of extra tape, on his back. Tape recorders—weighing less than fifteen pounds but with a frequency response of 30 to 15,000 cycles per second —are adequate for most of the sounds audible to human beings. The biologist, who used to shy away from problems involving sound as something better left to the physicist, now finds ready-made, sound equipment nearly as easy to obtain as a new typewriter. Not only can he record and play back sounds, but he can (if he has two or three thousand dollars) analyze them in terms of pitch, duration, and intensity.

HOWEVER, biologists have been itching to get into the fray since the earliest days of the phonograph. P. P. Kellogg notes that a gramophone reproduction of the song of the brown thrasher was featured at the 1898 meeting of the American Ornithologists' Union. Two years later, a biologist used a phonograph to try to find out whether the vocalizations of capuchin monkeys represented communication or merely a racket. Hi-fi was,

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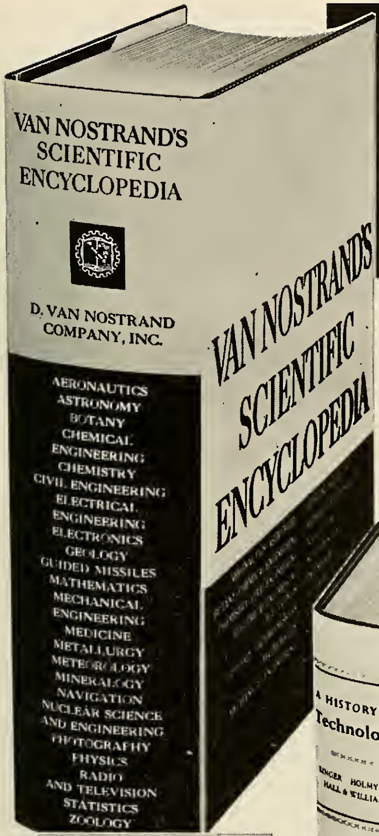
MR. BOGERT is Chairman and Curator of the Department of Amphibians and Reptiles at THE AMERICAN MUSEUM.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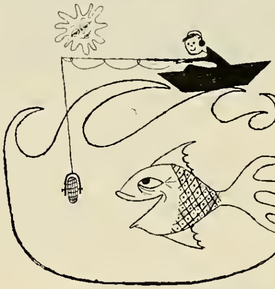
City____________________Zone____State__________ of course, not even an expression then, much less a reality, but the dubious quality of the reproduction inhibited neither the monkeys nor the investigator. He was convinced that the animals attached special meaning to at least thirty different varieties of sound.

While the phonograph at the turn of the century opened a door to experiment, it did not pave the way to success. The road was rougher than it looked and many obstructions remained. Frank E. Lutz, who recorded and studied crickets over a forty-year period, asks rather plaintively (in *A Lot of Insects*, G. P. Putnam, 1941), "Why must all sounds made by insects be 'useful'?" In his recent book, *Listening in the Dark* (see Natural History, May, 1959), Donald R. Griffin describes the pitfalls and obstacles encountered in his studies of hearing, sound production, and echolocation in bats, to which he has devoted much of his career.

The myth of the "silent sea" might still be perpetuated but for the wartime development and use of devices for the detection of submarines or, as it turned out, a wealth of other underwater sounds. A microphone for underwater use, the hydrophone, led to all sorts of discoveries. Investigators found porpoises emitting sounds comparable to those of bats. Like bats, porpoises depend on echolocation — the reflection of high-frequency sounds, which permits them to locate objects by auditory cues.

Many sounds emitted by animals were undetectable until recently. Where the phonograph of fifty years ago covered frequencies ranging roughly from 200 to 5,000 c.p.s., hydrophones sensitive to frequencies above 200,000 cycles have been devised. Few adult human beings ordinarily hear sounds as high in pitch as 15,000 c.p.s., although under suitable conditions some children are aware of sounds up to 25,000 c.p.s. But the best of us are easily outclassed by the lowly katydid—which responds to sounds ranging up to at least 45,000 c.p.s. W. N. Kellogg's investigation of hearing in porpoises discloses their reaction to vibrations of 80,000 c.p.s.

The latter's work with porpoises exemplifies a new trend in the growing field of biological acoustics. It is no longer necessary for the scientist to speculate in vague terms or try to describe sounds by comparing them with creaking doors or other familiar noises. Electronic devices enable him to describe sounds with precision and supply aural documentation as well. This holds true of ultrasonic sounds, those of higher pitch than we can hear, that can be brought within our range by reducing the playback speed of the recording tape. The underwater clicks of porpoises recorded by W. N. Kellogg can be heard on *Sounds of Sea Animals, No. 2* (Folkways, FX 6125), at six speeds, ranging from normal to 1/64. Each successive reduction in speed discloses peculiarities present on the original tape in the ultrasonic frequencies previously undetectable to human ears. The listener can even hear the echoes, as the sounds bounce back from objects and provide the porpoise with a means of locating its position.



Thus scientists can share their discoveries with anyone owning a modern phonograph. Many of the records on the market are by-products of scientific investigations, ranging from the Navy's work to ascertain the source of the clicks, groans, hums, or grunts interfering with its sonar to studies more directly concerned with the reactions of animals, their behavior, and their senses. The crustaceans and fishes heard on *Sounds of Sea Animals, No. 1* (Folkways, FX 6121) were recorded by the Naval Research Laboratory at varying depths in the Atlantic and Pacific oceans or in tanks where the creatures could be isolated and sound sources pinpointed. Another long-playing record, *Sounds of North American Frogs* (Folkways, FX 6166)—for which this reviewer is responsible—stems from an investigation of the role of mating calls, warning croaks, distress signals, and other sounds intimately related to reproduction and survival among amphibians. The startling vocalizations of several animals in the zoo fill one side of *Sounds of Animals* (Folkways, FX 6124), while the other side documents a scientific study of sound signals and their significance in the lives of various domestic animals.

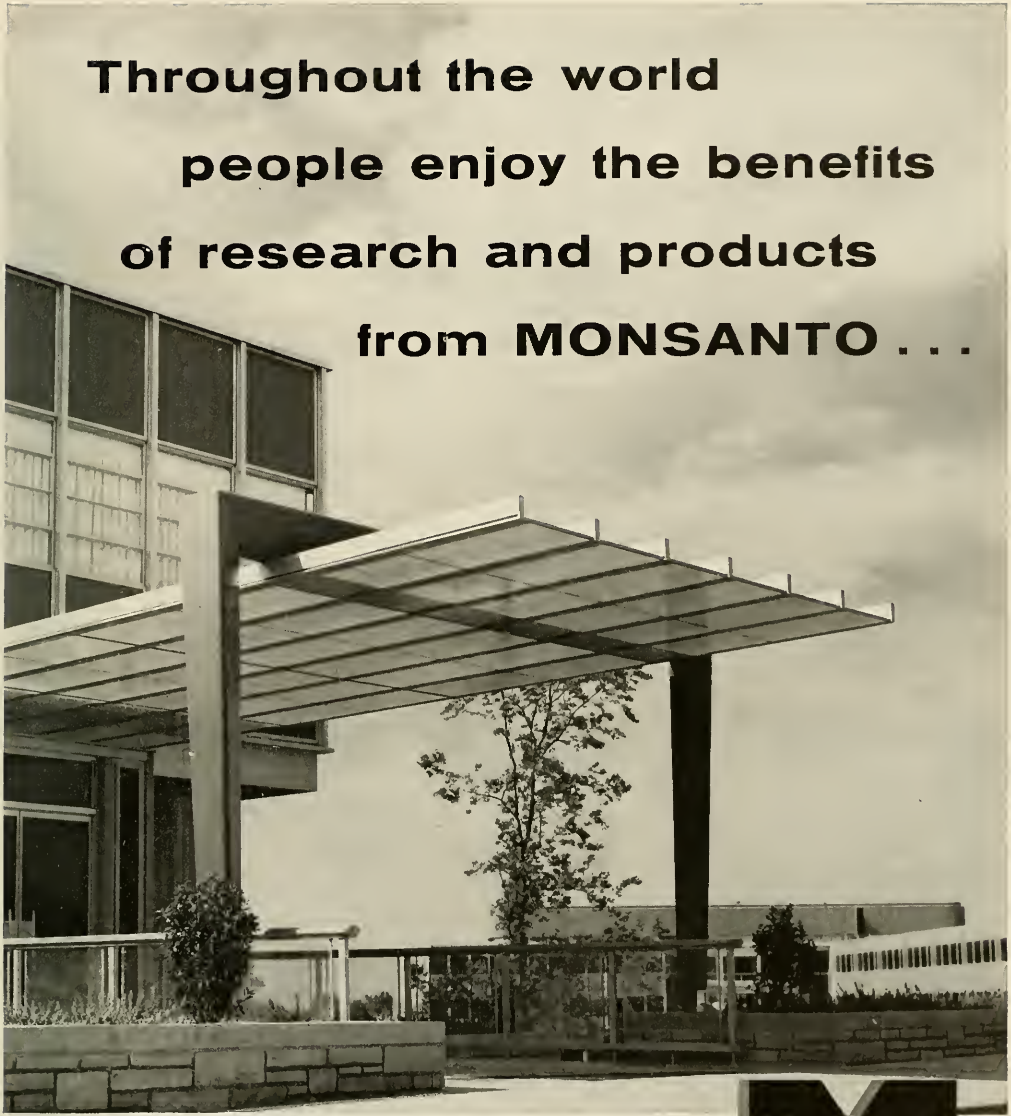
The mating call of the frog entices the gravid female to the breeding pond: the hen emits sounds that bring her chicks to her side. There is no intellectual motivation for such sounds, for animals have no language in the proper sense. They do not converse, even though they employ sound as a means of communication. So much has been learned about auditory communication in animals within the last decade that the American Institute of Biological Sciences is sponsoring a book dealing with the subject. Plans are under way to have the text supplemented with recordings.

Several investigators have studied communication among birds. Although some birds are far from being pleasingly vociferous, there is no denying that others produce some of the more melodious sounds in nature. Ornithologists are understandably anxious to share their auditory experiences, as P. P. Kellogg and A. A. Allen demonstrate in the series of records issued by the Albert R. Brand Bird Song Foundation of Cornell University. The prevalence of bird watchers is attributable as much to the vocal abilities of birds as to their profusion of plumage. Kellogg and Allen manage to deal with both in *Songbirds of America in Color, Sound, and Story*, which consists of an informative twenty-seven-page booklet, handsomely illustrated with color photographs of the twenty-four birds whose voices are heard on an accompanying ten-inch, long-playing record.

The long-play records issued by Cornell University—as Vols. 1 and 2 of *American Bird Songs*—cover the distinctive, if not always melodious, calls of more than a hundred species found within the borders of the United States. Individual bands on these records roughly group the subjects by habitat, with such titles as "birds of the north woods," or "birds of the lakes and marshes," and there are also bands devoted to game birds, and North American warblers. Those who want more restricted regional coverage have little choice at present, but *Western Bird Songs* and *Florida Bird Songs*—issued by Cornell on ten-inch, 78 rpm records—each include ten outstanding vocalists (strictly songsters for the West, but with such fancy noisemakers as the barred owl and the sandhill crane for Florida).

Most of us are familiar with the vocal dexterity of the mockingbird, which, with its ability to imitate other birds, makes it a natural target for soundhunters. When a technician and an ornithologist get together and aim a microphone at a particularly talented bird (in this case, near Weston, Massachusetts), they wind up with something eminently worthwhile—as shown in another Cornell ten-inch, 78 rpm. record, *The Mockingbird Sings*. Here we have documentary evidence of the bird's astonishing ability to mimic more than thirty other birds.

Equally interesting (but unfortunately not so readily obtainable) is an Australian recording (*The Superb Lyrebird:* Columbia; SEGO 70006, 45 rpm.), of another accomplished vocalist and mimic. Noted abroad more for its plumage, the male lyrebird has a voice quite as spectacular as its tail feathers. This forest singer imitates the weird call of the kookaburra or the notes of the introduced blackbird with the ease of a mockingbird mimicking a whippoorwill.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The United States has no monopoly on avian coloraturas, mimics, or fancy racket-makers. Tropical forests often reverberate with whistles, cries, or calls emanating from birds. South of our border, one may hear the haunting notes of the quetzal, the maniacal cry of the laughing falcon, or the clacking of the chachalaca. These and the calls of some seventy other birds, recorded by Irby Davis, may be heard on a Cornell record called *Mexican Bird Songs*. If you prefer something farther afield, try *Voices of African Birds*, also produced at Cornell but recorded and narrated by Miles North, whose British accent adds a further touch of the exotic.

Throughout a career as a technical editor in the petroleum industry, Jerry Stillwell pursued ornithology as an avocation. Upon his retirement, he knew precisely what he wanted to do. With a house trailer, recording equipment, a wife, and abounding patience, he set out to be on hand wherever and whenever birds were to be heard. Working as a team in the field, the Stillwells also coordinate their efforts in narration—with Jerry, the birds, and his wife, Norma, taking turns at the microphone. Their bag, to date, totals 495 songs and calls (of 164 species), neatly packaged in an album of three long-playing records called *National Network of American Bird Songs* (FICKER). Or the records may be purchased separately, with two "volumes" of *Eastern Bird Songs* and one of *Western Bird Songs*.

THUS, cooped-up urbanites, armchair naturalists, and amateur bird watchers have a rather wide choice of records. Cricket watchers are far less fortunate, although Cornell has issued one record, *Songs of Insects*, that offers the sounds of crickets, more crickets, and a few katydids, grasshoppers, and cicadas. Crickets sneak into the background of many recordings, and if there is less diversity in chirps than in true vocalizations, it is nevertheless amazing that such small creatures produce such loud noises.

A cacophonous concert of katydids, cicadas, or crickets may be monotonous, but, as Hollywood realizes, it is often an integral part of the environment. Cricket chirps dubbed in the sound track lend an air of authenticity to night scenes. If the setting is along a river or a swamp, the voice is that of the Pacific treefrog. At least it was—and those responsible for sound effects evidently believed the creature to be world-wide in distribution. This situation has improved, however. In *The Bridge on the River Kwai*, the night sounds along the river include a trill suspiciously similar to the mating call of the giant toad of the American tropics. Indeed, it could be that same species, for the giant toad has been introduced in many Pacific islands (to aid in controlling insect pests in the cane fields) and has been reported from Ceylon, where the picture was filmed.

The bird voices on the *Kwai* sound track may or may not represent species from the region, but they do provide an appropriate effect. This was the idea behind Harry Tschopik's use of the sounds made by rain, insects, frogs, birds, and such animals as howler monkeys as a background for the Museum exhibit concerning the Indians who inhabit the Upper Amazon. Called "*Men of the Montaña*," it opened at The American Museum of Natural History in 1951 and

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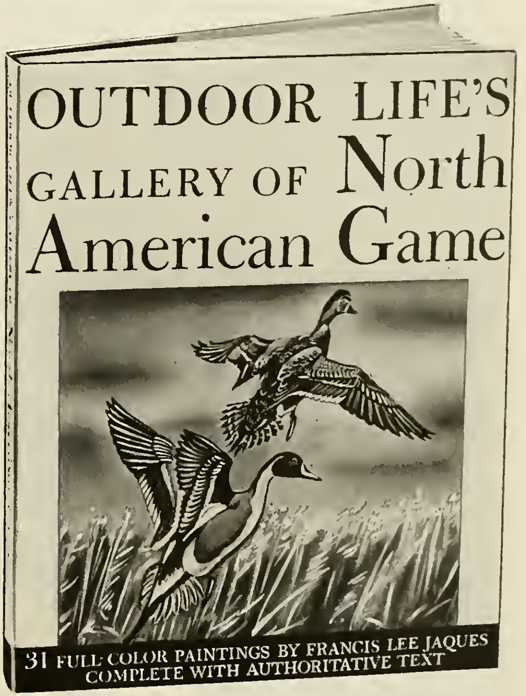
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Tschopik's exhibit proved to be of exceptional interest. To obtain suitable sounds, Tschopik enlisted the aid of Moses Asch, of Folkways Records and Service Corporation and Asch, in turn, got the full co-operation of such phonophiles as Kellogg and Allen of Cornell and Herbert Knobloch at the Bronx Zoo. The track that resulted from this combined effort has been released in record form as *Sounds of a Tropical Rain Forest in America* (FOLKWAYS, FX 6120).

This effort marked the beginning of a series of releases providing aural documentation of regions or environments, rather than of individual groups of animals. A Cornell record, *Jungle Sounds*, was made from taped voices of various animals inhabiting Barro Colorado Island and the adjacent jungles of Panama. In turn, the flutter of hummingbird wings, the purring of a puma, the sizzling sound made by the rattlesnake, the hooting of a horned owl, and the racket accompanying a ripsnorting thunderstorm (followed by a flash flood and choruses of spadefoot toads) are arranged in a sequence of time and season on *Sounds of the American Southwest* (FOLKWAYS, FX 6122).

WHAT people like to hear may be largely a matter of taste, but taste is conditioned by past experience. A drab, intrinsically uninteresting bird call may excite the ornithologist who has heard the sound in the field. The same ornithologist may be bored listening to the excellent reproductions of the calls of thirty-four frogs and toads on *Voices of the Night* (CORNELL), unless one or two of them take him back to pleasant memories of a childhood summer. The average person who listens to *Sounds of a South African Homestead* (FOLKWAYS, FX-6151) may not accurately visualize the land of the Zulu, where Raymond B. Cowles recorded the great variety of sounds incorporated therein. But the record conveys a comprehensive auditory impression, which should have meaning to anyone who ever lived on a farm in his own country. There are the birds, the amphibians, the insects, the counterparts of the creatures inhabiting homesteads throughout the world, along with the human inhabitants, the Zulus, whose wedding music, horn-blowing, and ox wagons rumbling across the land, complete the aural documentation of an environment that is at once distinctive and yet reminiscent of many others.

Somewhat the same idea was employed by Kellogg and Allen when they produced *An Evening in Sapsucker Woods* (CORNELL). The sounds, all recorded in a wildlife sanctuary in central New York, start in the late afternoon, when most of the birds are singing, and go on until dark—when only frogs, owls, and other nocturnal animals are heard. The result is satisfyingly effective.

OTHER ways have been used to explain or enhance the meaning of sounds on records. James H. Fassett, the supervisor of music on a radio network and an old hand with recorders, is described as knowing "his sounds, speeds, and splices." His commentary and analysis of *Music and Bird Songs* (CORNELL), taped originally for a radio program, deals with the sounds as such, rather than with their biological significance. The voices of six frogs and ten birds are contained on the record. They are all heard, first, at normal speeds. Then, Fassett explains what happens when some of the songs are heard at reduced speeds. Slowing down the fast, high-pitched twittering of small birds has the effect of magnifying the structure of the sound. At lower frequencies, changes in pitch and quality become emphasized and readily detectable. Twittering comes to resemble the warbling of larger birds.

The success of this first effort may have inspired Fassett's *Symphony of the Birds* (FICKER, C-1002), produced by combining and playing the songs of twenty birds at a variety of speeds. Some are reproduced normally, but others are

(continued on page 416)

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"Let me see what he's found."

The clam digger at his work.

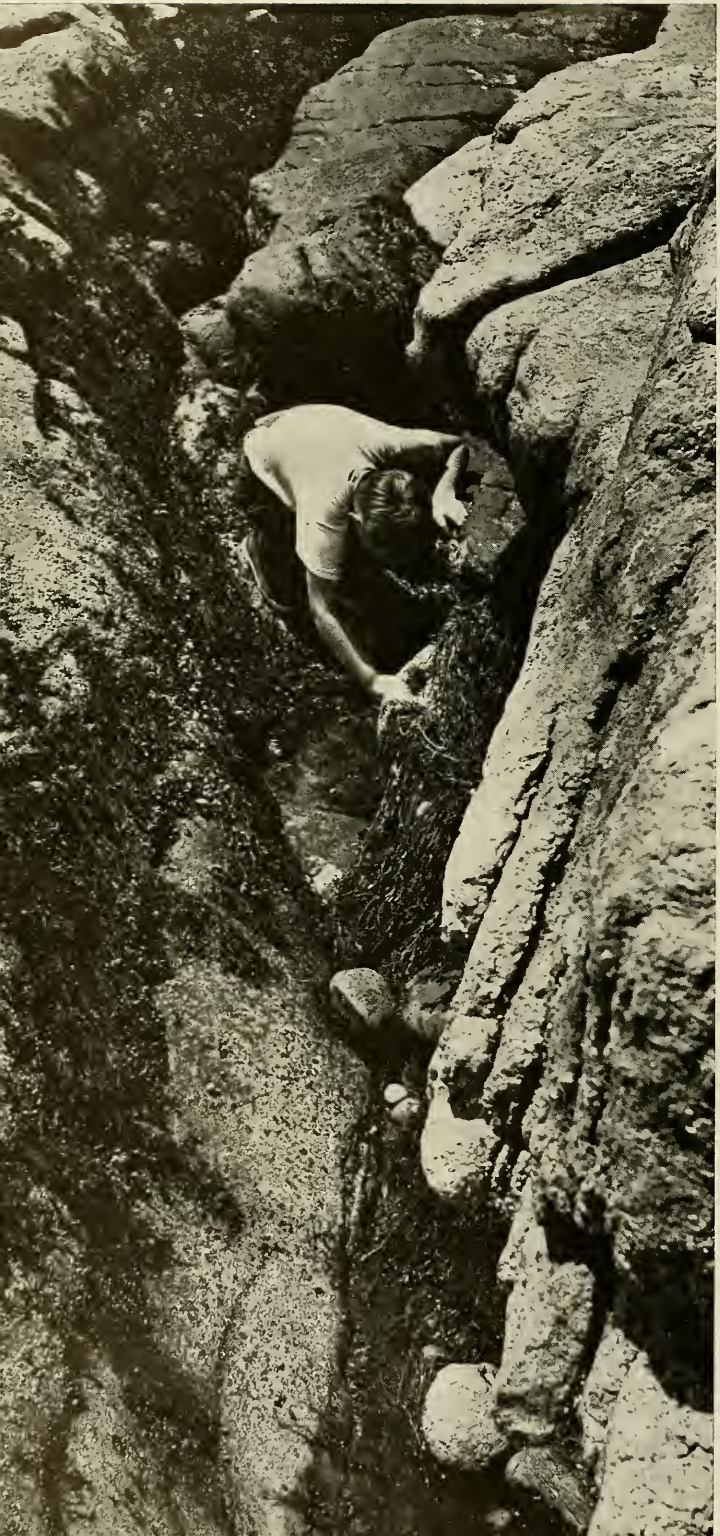
A Summer's Learning

Treasures from the sea may open a child's eyes to all of nature

By JOHN HAY   Photographs by ARLINE STRONG

EXPLORATION begins in childhood, part of the natural game of "find-out"—of touching, hearing, seeing for the first time. Children are greedy for what is ahead, and anxious to hang on to what they find. "Finders, keepers. Losers, weepers," is an old and honorable saying that may apply to a seashell, or a shellfish, as well as a coin or a marble. The field of valuable goods is as wide as the natural world. In any case, the feeling of first possession is important: it is good to have things in the pocket. And, as the pictures on these pages amply testify, to share things is of equal value: "Come and see!" Then, with average luck, one may start upon a lifetime of seeing. Nature's riches are found everywhere, but perhaps the Atlantic Coast, especially in the rocky, tidal area of the north, is one of the higher on the list of hunting grounds for young explorers. There is an immense amount of invisible life—in mud or sand, in the perpetually moving ocean waters—but also much to be found on the surface, especially at low tide, and to be uncovered and dug out. In Maine, where Arline Strong made the pictures on these and the following pages, a boy may wake up on a summer morning to the musical call of herring gulls across the water of one of the innumerable coves and inlets along the coast, or to hear a flock of crows communicating loudly in the spruce trees overhead or a white-throated sparrow lancing his sweet, clear song out from the shadows. Salt water runs and stirs along the cove's edge, lapping at the rocks or the wharf pilings below the house. He hears and absorbs these sounds without attention, since there is a day to discover. It may begin with a swim in the sometimes shockingly cold water, or a brief rowing expedition in a dory.

MR. HAY, of Cape Cod, here provides commentary on a summer's portfolio by MRS. STRONG, a talented New York photographer of nature and children.



THEN the tide begins to turn and its waters move down the sides of the rocks, revealing great streaming covers of weed and uncountable populations of dog whelks and periwinkles. The water eases back from the cove. Perhaps a thick morning fog begins to clear up after lying low — almost impenetrable — across the water. Hot sun begins to make itself felt and, on the ebb tide, mud flats start to shine between the rocks. The landscape is filled with tumbled stone and massive rock—very slippery, even with sneakers. Fall, and you may scrape your hand or arm on the sharp white shells of barnacles or the rough, rotting surface of the rock itself, where it is not covered with algae. Crevasses open up between the rocks, sometimes narrow, deep, and inviting. Tide pools, colorful with algae, shine like gardens and hermit crabs scuttle across them, their housing on their

Hunting in a rock crevasse.

backs. If a boy is interested in putting pressure on the family to dine on clam chowder again, he takes a pail and clam rake along, and digs in the mud for a harvest that is usually plentiful. The softshell clams come out covered with black mud—intact, if he has some experience in the art, otherwise in bits and pieces. They are, as their name indicates, fragile, and may break when jabbed by the prongs of a clam rake. Low-tide agriculture is one temporary way of life for a boy. Or he can be a collector, with some of the rudiments of science in his head. But it's just as good to be an open-eyed beginner. The watchful, careful walker can always find something in these fertile regions. Deep under the brown rockweed he may come upon green sea urchins and prickly starfish or seek out the elusive crabs that may be hiding along the edges of the shining tide pools.

Investigator studies the edge of a tide pool.

Plant under scrutiny is *Ascophyllum nodosum.*

The soft-shelled clam, *Mya arenaria.*

Sweeping the water with a sieve.

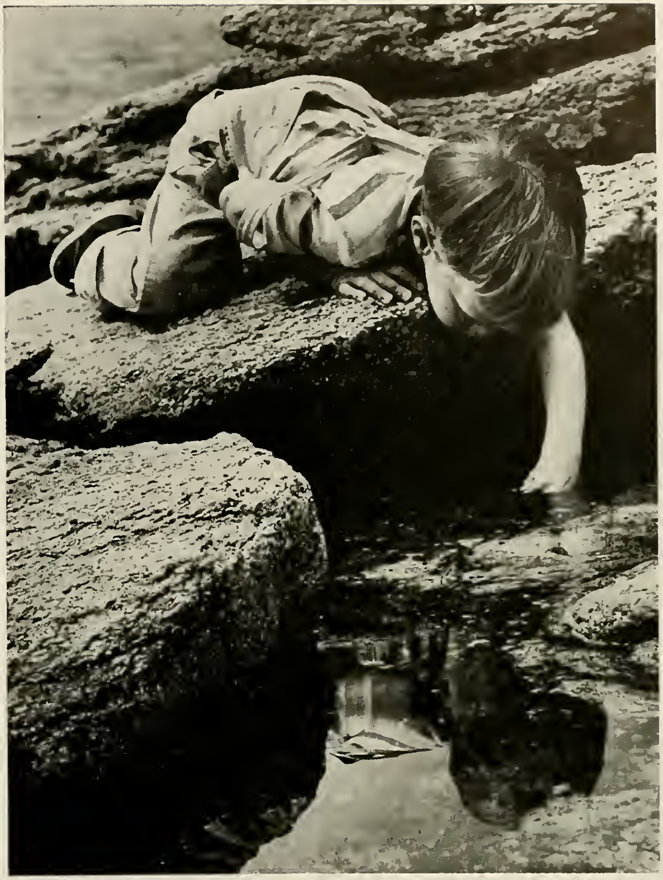
THERE are northern rock crabs and green crabs, very often young ones at this time of year, that a boy can find sidling across the bottom of a pool, or in the weeds. He can watch hermit crabs, sometimes in an exchange of houses or fighting for the possession of a new one. He can even stop for a minute and look at his own reflection in the water, out of a beginner's curiosity.

Everything he finds is food for speculation, present or eventual. How long does the jellyfish—now stranded in the mud—live? Does it have children? How does it eat? And what?

The white sea jelly, *Aurelia aurita.*

TO EXAMINE the feet of a starfish, the spines of a sea urchin, the beard of a blue mussel, to learn how to pick up a crab without being pinched, to tug at the slippery rock weed and find out how firmly it is anchored . . . these are some of the ways to learning. Everything suggests unfinished business. Each life in this world of the shore, co-ordinated in some way with all the other life around it, is rich with untold fact and circumstance. Getting some of them in hand—and mind—may be the first step in a long journey of discovery.

The rock crab, *Cancer borealis.*



Exploring the depths of a still, tide pool.

A starfish, bottom side up.

A green sea urchin in hand.

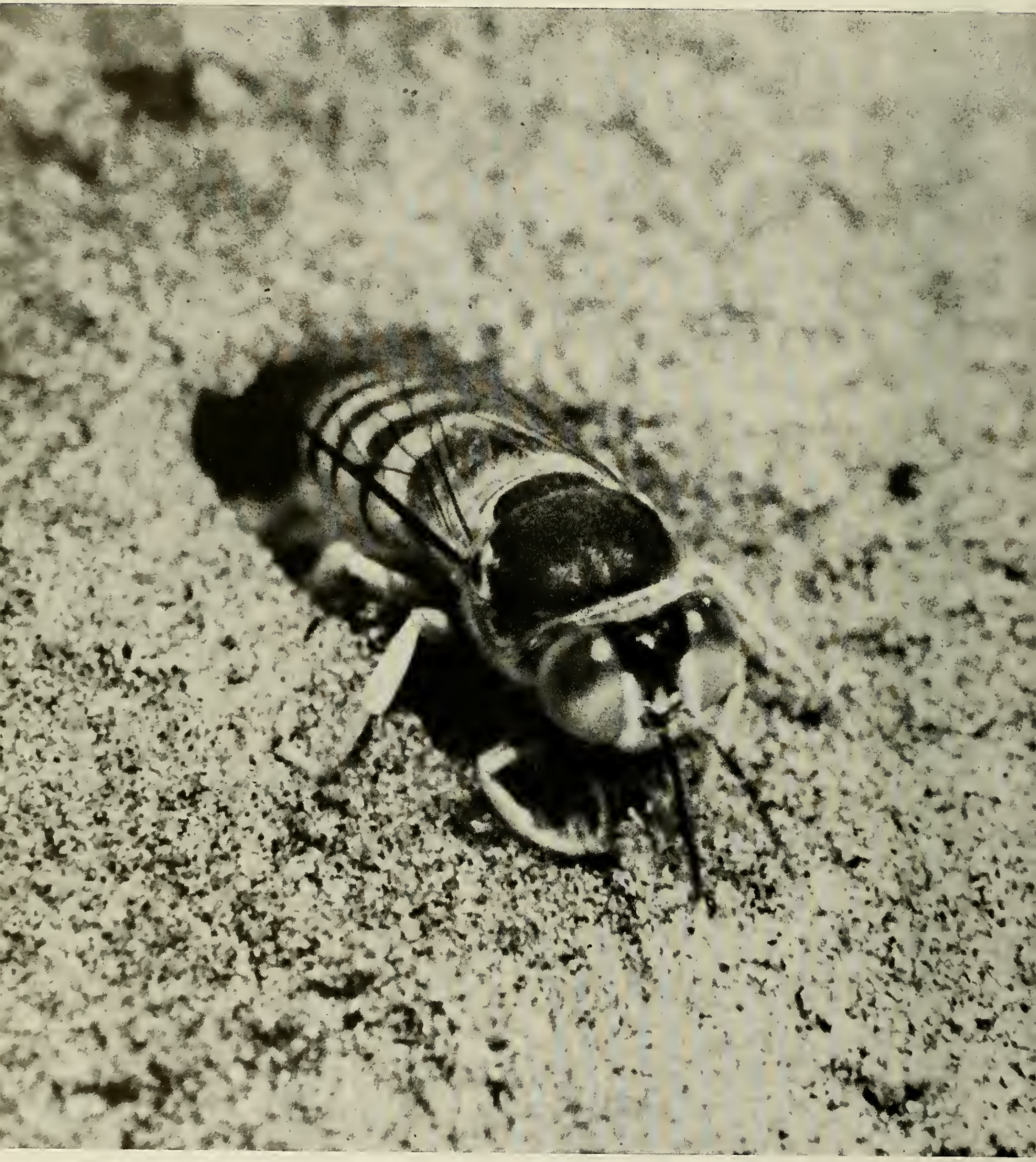
Hermit crab in periwinkle shell.

A boy's perch confronts
the island's roaming water.

"Those gulls certainly don't
worry about table manners!"

Late afternoon: nice, warm mud —
and a pail full of trophies.

ADAPTATION OF A



Closing her nest, female *Bembix pruinosa* bends forelegs inward so that the long spines on the tarsi scrape the sand backward beneath the body. Since adult opens nest entrance only to enter or to leave, parasites cannot attack the larva.

SAND WASP

By Howard E. Evans

Digging with forelegs, *Bembix* raises its abdomen to allow a passage for sand.

There is scarcely a place on the face of the earth more sterile and uninviting than the central part of an active sand dune. The slightest wind picks up handfuls of sand particles and drives them along. The sun pours down torrents of heat and the bright surface hurls it harshly back. Any rain that falls percolates so rapidly through the sand that it leaves no impression at all. Temperatures often rise to 90–100° F. by day, and the sand surface commonly measures as much as 125° F., or even more. Studies have shown that physical conditions in sand dunes are very much the same the world over, whether it be in the Sahara or in Aweme, Manitoba. Even a plant sturdy enough to withstand the heat and dryness soon has the sand blown out from under its roots or piled in drifts over its branches. Little wonder that such places are so devoid of life!

But visit a sand dune—not in the cool of evening or of winter or spring, but in the hottest part of the day and in the hottest part of the year—and you may find it teeming with a particular insect, which, in fact, occurs nowhere else. This is the sand wasp *Bembix pruinosa*, an insect that is over half an inch in length and is brightly patterned with pale, yellow-green markings. At the proper season, one rarely finds a sand dune east of the Rocky Mountains that lacks a thriving colony of these wasps. Along with the wasps often occur some of their parasites—certain species of flies and hairy, wingless wasps known as velvet ants. But that is very nearly all; the wasps and their parasites make up almost the entire diurnal fauna of the dunes.

Only a remarkable insect can thrive in this habitat. It must be able to adjust to or avoid the extremes of temperature and aridity, not only for itself, but also for its more delicate eggs and larvae. It must be able to rear its progeny where they will not be exposed or buried deeply by blowing sand. It must be able, without fail, to find its nest in a vast expanse of shifting sand. And it must be able to survive in spite of numerous parasites. It so happens that many of the parasites of sand wasps are not host-specific—they are not restricted to one host, but attack a variety of different wasps in different situations. Here *Bembix pruinosa* is at a distinct disadvantage: the parasites are wide-ranging and ever-present, but the wasps are restricted to suitable parts of active sand dunes. Ordinarily, when parasites cause the decline of a population, they bring about their own decline, too, since they create a shortage of suitable hosts. But not so here: if *Bembix* declines, the parasites continue to live on other hosts in surrounding areas, areas that *Bembix* is unable to invade. Only by "outwitting" its parasites can this species maintain its numbers.

Paralyzed horsefly is carried into the nest as food for larval *Bembix*. When larva is young, three flies a day may suffice; later, twenty may be needed.

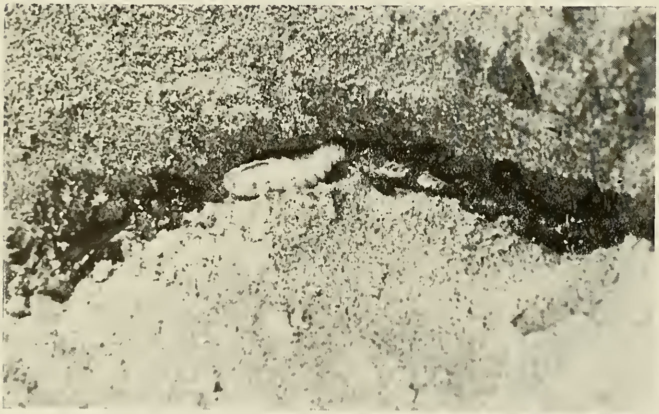
By various and often unique behavioral devices, the pruinose *Bembix* is able to accomplish all these things. It is interesting, for purposes of comparison, to note that there are many other species of *Bembix* besides *pruinosa*—most of them living in more congenial situations and not nearly so restricted to one particular ecological niche. The behavior of many of these more "ordinary" sand wasps is simplicity itself. For example, *Bembix spinolae*, which occurs all over eastern North America, digs its burrow in sandy gardens, waste places, sand pits, beaches, and the periphery of dunes. At the end of this simple burrow, the bottom of which is only three to six inches deep, the egg is laid in a small, oval cell. In a day or two, after the egg hatches, the wasp captures and stings a number of flies and presents them to the larva. When the larva is small, two or three flies a day suffice, but after a few days the larva requires many more flies a day, as many as twenty. The larva feeds only upon the soft parts of these flies, leaving a mass of wings and hollowed-out bodies, which eventually form a mat on the bottom of the cell. After about six days the larva begins to spin its cocoon, and the female wasp fills up the burrow and begins a new one nearby.

Bembix spinolae has many parasites. Some of them attack the larva directly—such as the bee flies, which drop their eggs into the nest entrance, and the velvet ants, which enter the cell and lay their eggs through the wall of the cocoon. Others live upon the bodies of the flies in the cell, forcing the mother wasp to bring in a great many additional flies and often causing the wasp larva, in spite of this increment, to die of starvation. This type of parasitism is exhibited by quite a number of small flies that deposit small, live-born maggots in the cell or on the body of a fly as it is brought into the nest. These larvae grow rapidly into ravenous maggots, as many as a dozen or more of which may inhabit a single cell.

Bembix spinolae seems to have few means of avoiding these parasites. The wasps do remove the telltale pile of sand at the entrance to the burrow, and they do keep the burrow closed at the entrance nearly all the time—mechanisms doubtless functioning to make the nest as inconspicuous as possible to parasites—but apparently the species thrives mainly because it is ecologically so versatile. That is, if parasites become overly abundant, individuals radiate out into neighboring habitats and establish new colonies — something a species like *pruinosa* is unable to do.

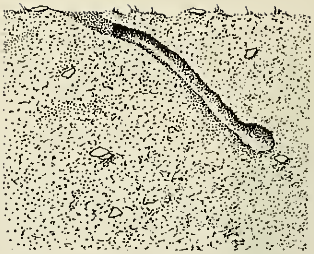
An associate professor of entomology at Cornell, DR. EVANS has studied solitary wasps from coast to coast. He is now spending a year in Mexico.

THE nesting behavior of *pruinosa* is very much more elaborate than that of *spinolae*. As might be guessed, the nests are very much deeper than *spinolae*'s. The top layers of sand, in a dune, are dry and exceedingly hot; but a foot or two down, the sand is much cooler and more moist. Also, in a shallow nest the cell might soon be exposed to the deadly heat of the surface by the action of the wind. In small, sheltered dunes I have found the average depth of the cell to be only about eight inches. In larger dunes the depth of the cell varies from ten to twelve inches, and in one very large dune system along the banks of the Red River in Texas, I found the cells to be nearly two feet beneath the surface. Apparently, isolated colonies of the wasp become adapted to conditions in their area: the more blowing sand, the deeper the nests. It would be interesting to transplant wasps from a colony in a small, protected dune to a very large dune and study their survival.



CROSS SECTION of cell shows *pruinosa* larva with flies arranged in a row to be eaten. Method contrasts with *spinolae*'s, where food is packed in cell at random.

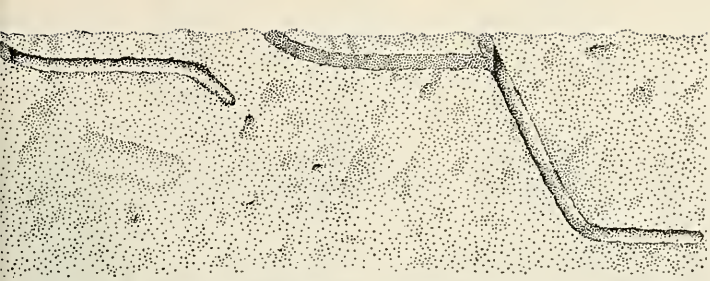
Not only is *pruinosa*'s nest deeper than *spinolae*'s, it is considerably more complex. When the female is about to start a nest, she digs a bit in one spot, then backs up an inch or two, digs again, backs up again and so on. The result is a series of little pits connected by a straight line. If the texture of the sand is suitable, she then digs down an inch or two and prepares a broad, horizontal tunnel below the sand surface—and just beneath her line of little pits, which clearly function to insure that no serious cave-ins would occur here. This "preliminary burrow" may be as much as twenty inches long. After it is finished, the wasp returns to the entrance, levels off the pile of sand that has accumulated, then enters the burrow and closes it from the inside. She then goes to the far end of the preliminary burrow and begins to dig obliquely down into the sand, pushing the soil from this "true burrow" into the preliminary burrow, which is soon completely filled up. At the bottom of the true burrow, which may also be twenty inches long, she then constructs a cell—not a simple, oval cell as in *spinolae*, but a slender chamber averaging eight inches in length. Thus, the total length of the nest excavated by the half-inch *pruinosa*, including preliminary burrow, true burrow and cell, may be as much as a yard and a half. Yet this nest is used for rearing only a single larva, and a new one is constructed for each successive offspring.



BURROWS of *B. spinolae*, shown above, and *B. pruinosa*, seen in two stages at right, illustrate complexity and size of

After finishing her nest, the female wasp lays her egg at the far end of the cell and proceeds to wait inside the nest until the egg is nearly ready to hatch, a matter of about two days. Then she leaves the nest, going out this time not by way of the preliminary burrow, which has been filled with sand and abandoned, but directly up the true burrow and out to the surface. This involves preparing a new nest entrance, which is first cleared out by digging and then filled in briefly to make a temporary closure while the wasp goes off to catch a fly for her larva. Each day, the larva receives a few freshly paralyzed flies. But these are not merely packed into the cell as in the case of *spinolae*; they are lined up in single file along the very long brood chamber. The larva moves down the chamber as it feeds, consuming the flies one after another and leaving their remains behind. It is a temptation to say that the *pruinosa* larva is fed cafeteria-style!

If you examine a nest after the



pruinosa's burrow. *Spinolae*'s is only a shallow tube ending in an oval cell. *Pruinosa*'s is twice as deep, including preliminary burrow and long, thin cell for larva. Half-inch-long *pruinosa* may dig a yard and a half in building nest.

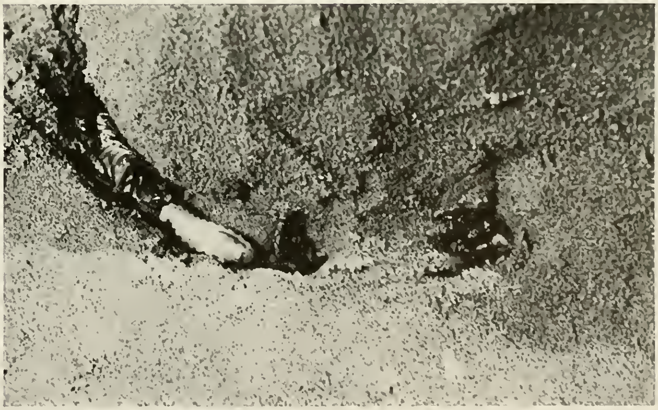
larva is three or four days old, you find that the larva has moved the greater part of the length of the cell. A short row of fresh flies, recently added by the mother, still confronts it. Behind it ought to lie the loose wings and hollowed-out carcasses of flies that have been devoured: but where are they? Does this larva eat the entire fly? A little further study shows that the cell is considerably shorter than it ought to be, and some further digging reveals the fly remnants in a compacted mass at the end of the original cell, walled off by a barrier of sand. Apparently, the mother wasp has raked all the debris into the end of the cell and then thrown up a barrier of sand to seal it off from the larva and the fresh flies. At about this time, the wasp closes up her burrow completely, leaving the larva to finish its growth on the remaining flies and to spin its cocoon. If, for some reason, the final closure of the nest is delayed a day, the wasp may prepare a second cache of fly remains and thereby shorten the cell still further.

For a long while, I was at a loss to explain this odd behavior. What possible difference could it make whether or not the larva lives in a clean cell or in a cell glutted with the remains of consumed flies (as in *spinolae* and most other species)? After digging out over eighty nests of *pruinosa*, I remarked upon one fact: this species is apparently never successfully attacked by the inquilinous, or commensal, maggots, which commonly infest the nests of other species. Such maggots live primarily in the fly debris, but when they are large they compete with the wasp larva for fresh flies, too. Perhaps *pruinosa* has found a way of overcoming them—for as a result of its practice, any small, developing maggots would soon find themselves segregated from the main part of the cell. It may be that *pruinosa* long ago, through mutation and natural selection, acquired the ability to sweep fly bodies into the tip of the cell. Once this was achieved, natural selection doubtless favored any elongation of the cell, so that this sweeping behavior could be performed more effectively. The remarkably long cell of the pruinose *Bembix* may have evolved in such a way.

At least, this seems the most plausible hypothesis for the strange nesting behavior of *pruinosa*. It seems probable, too, that the long, complex burrow has evolved as a means of deterring parasitism by flies and velvet ants. The closures of the nest, both temporary and permanent, are so thorough that the nest entrance is at all times quite invisible to a human observer, unless he sees the wasp entering or leaving. And perhaps it is as confusing to a parasite as it long was to me, to have the nest entrance shift as much as twenty inches between the start of the preliminary burrow and the completion of the nest!

Concealing the nest so thoroughly, and living as it does in broad areas of uninterrupted shifting sand, this wasp must have remarkable powers of orientation. I have often sat in the midst of a great colony of *pruinosa*, watching females return again and again to nest entrances that were completely invisible to me. All the while, the breeze blows lightly, and swirls of sand continually change the contours of the dune. The nearest tree is several rods away and the nearest tufts of grass lie well outside the wasp colony. And yet the wasps go back and forth without error, finding their own nest among the hundreds of seemingly identical nests scattered over the dune.

How do they do it? What landmarks can possibly be used? Much has been learned about animal orientation in recent years, but it would seem that *Bembix* is confronted with a far more difficult situation than, for example, the honeybee. Yet somehow it has solved this problem, too, just as it has solved the problem of rearing its offspring under seemingly impossible physical conditions and in the face of seemingly inescapable attacks by wide-ranging parasites. *Bembix pruinosa* is a remarkable animal—and probably even more so than we can yet appreciate.

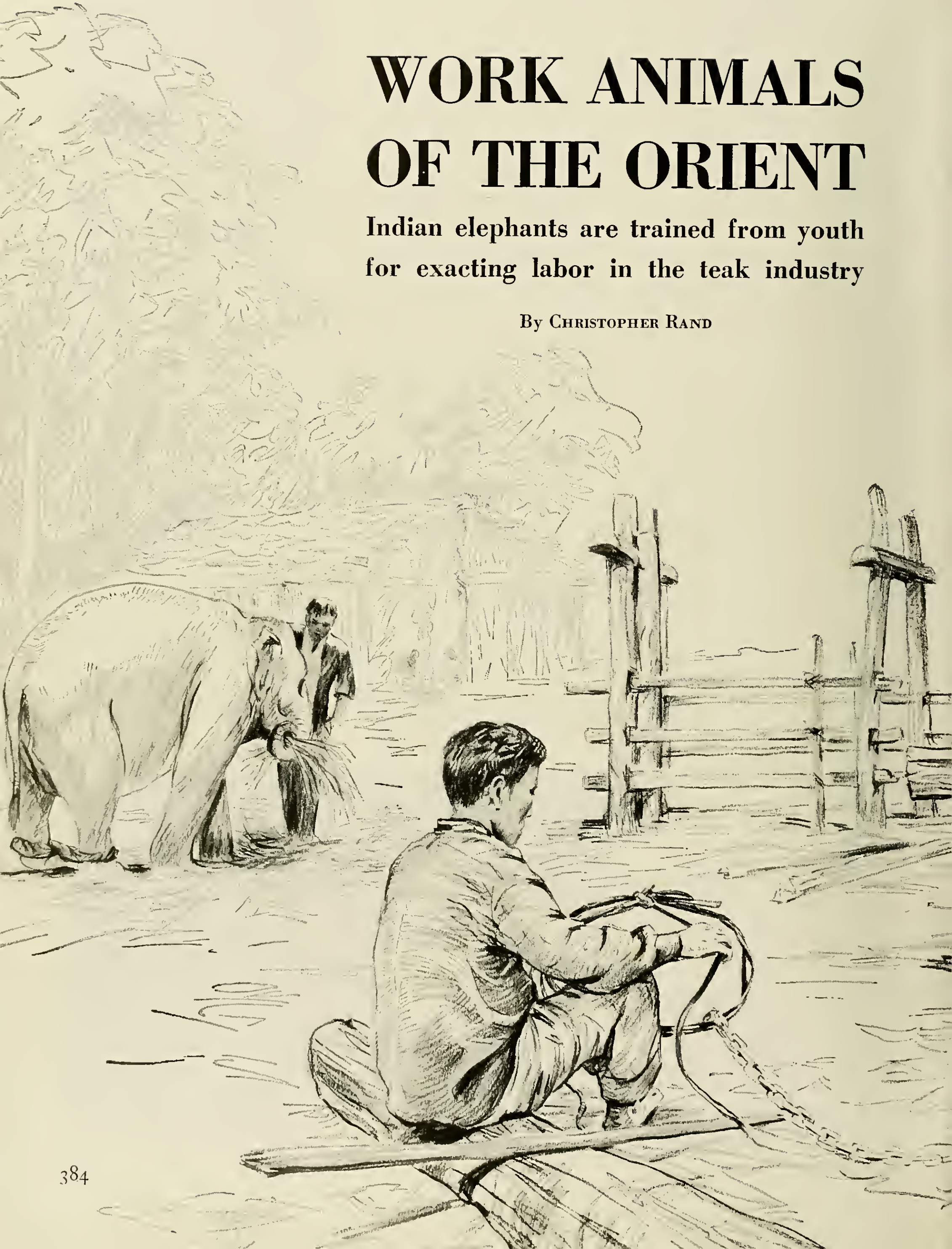


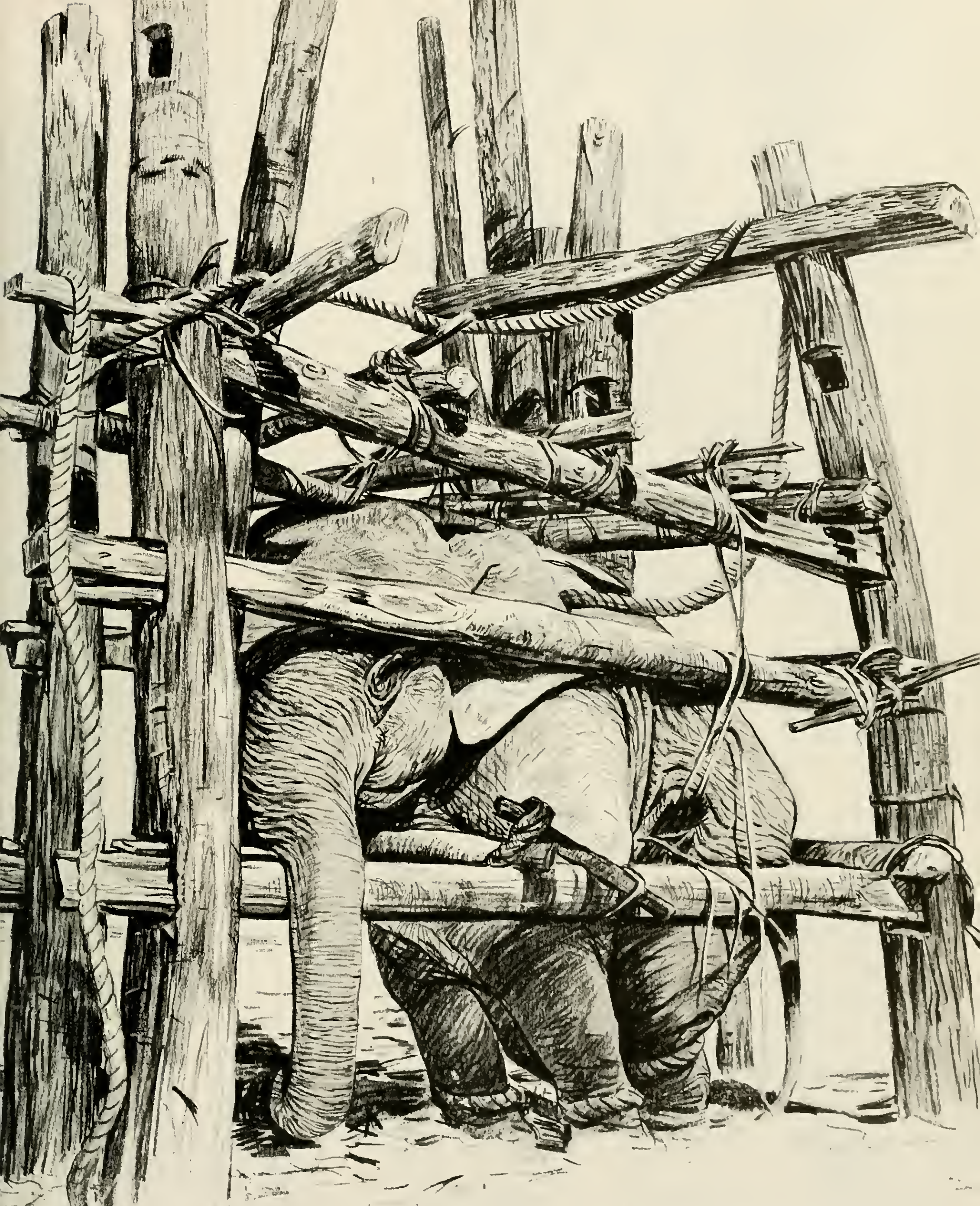
Few-days-old larva has already moved greater part of cell's length. Remains of flies it has eaten have been swept behind it and walled off by the mother.

WORK ANIMALS OF THE ORIENT

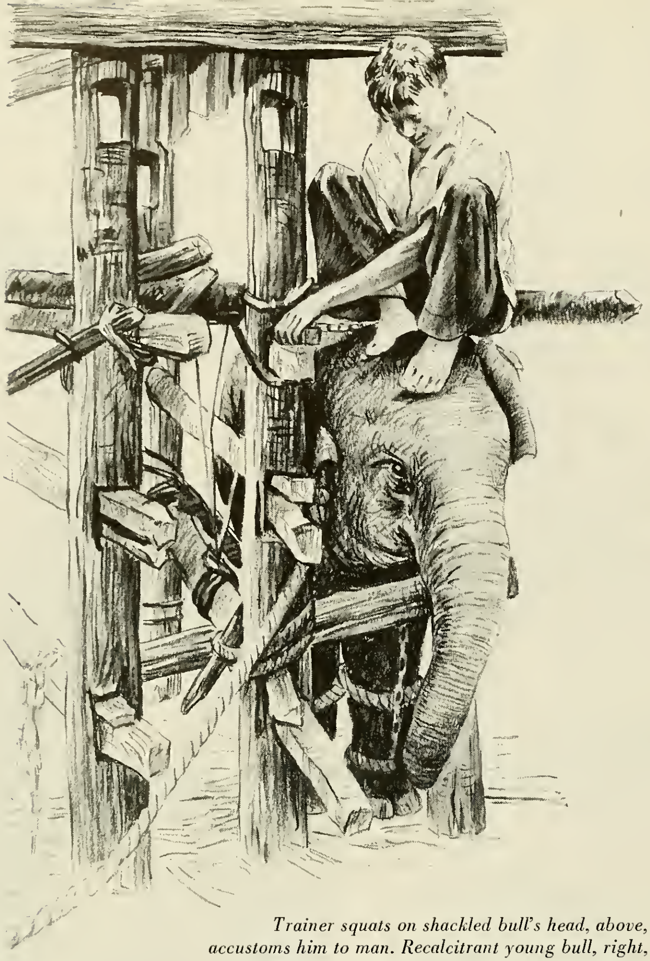
Indian elephants are trained from youth for exacting labor in the teak industry

By Christopher Rand





Exhausted at the end of his first day of training, a three-year-old elephant sags against his log cage. Here he will stay until he learns discipline.

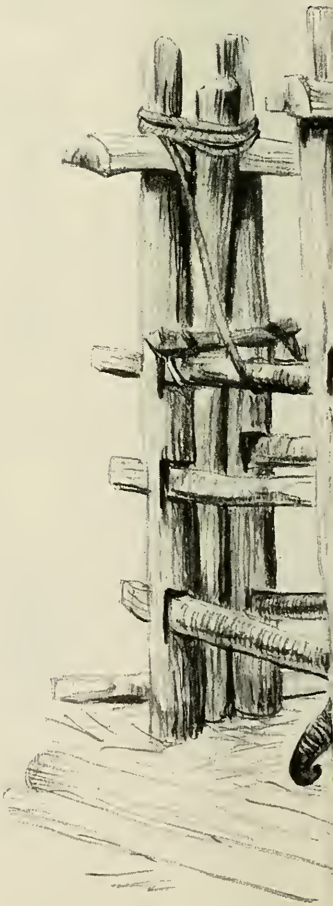


Trainer squats on shackled bull's head, above, accustoms him to man. Recalcitrant young bull, right, is efficiently boosted into cage by seasoned adult.

NOT LONG AGO, near Chiengmai in northern Siam, I caught up with an old ambition—to see elephants at work and learn something of this art. I arranged my study through the Borneo Company, a British firm that operates in the North Siam teak forests, and my first visit was to two little Borneo Company elephants—calves—that were being trained outside Chiengmai by a native professional. My companions and I walked the three miles from town to the elephants' training area on a jungle path. Being winter, it was cool in the shade, which was nevertheless broken by sun splashes. The jungle was not darkly roofed-over like those nearer the Equator, to the south. It was looser and more like our hardwood forests, although the trees were more exotic than ours: the scattered teaks, themselves, looked a bit like some nut trees, but with huge leaves, larger than fans. We walked on the dark smooth path, carrying dainties brought for the elephants—bananas and seed pods of the tamarind tree, which looked like brown string beans and were tart. As we neared our goal we heard a roar ahead. "It is the little male," I was told. "They must be punishing him." We went on, across a sparkling brook and a rise, rounded a bend and found the elephant camp below us, in a clearing.

Two elephant calves were penned in "crushes"—log cages built to fit and hold them tight. The two cages stood together at the clearing's far side. At the near side was a hut, thatched in leaves, for the trainer and his crew. Each crush was a corral in miniature: four posts, a foot thick, were set in the ground to form a truncated V. The elephant calf's head was in the narrow end of the V and its rear in the broad one. The four posts were joined by logs, mortised into them and lashed with creepers—three logs to a side, one low, one high, and one between, where the elephant's gray body was widest. Smaller logs were tied on top.

THE crushes looked solid, but much of their strength was in their closeness. The male elephant — the larger of the two, although it turned out, the younger—was bound fast in his. At the hump of his back, he was



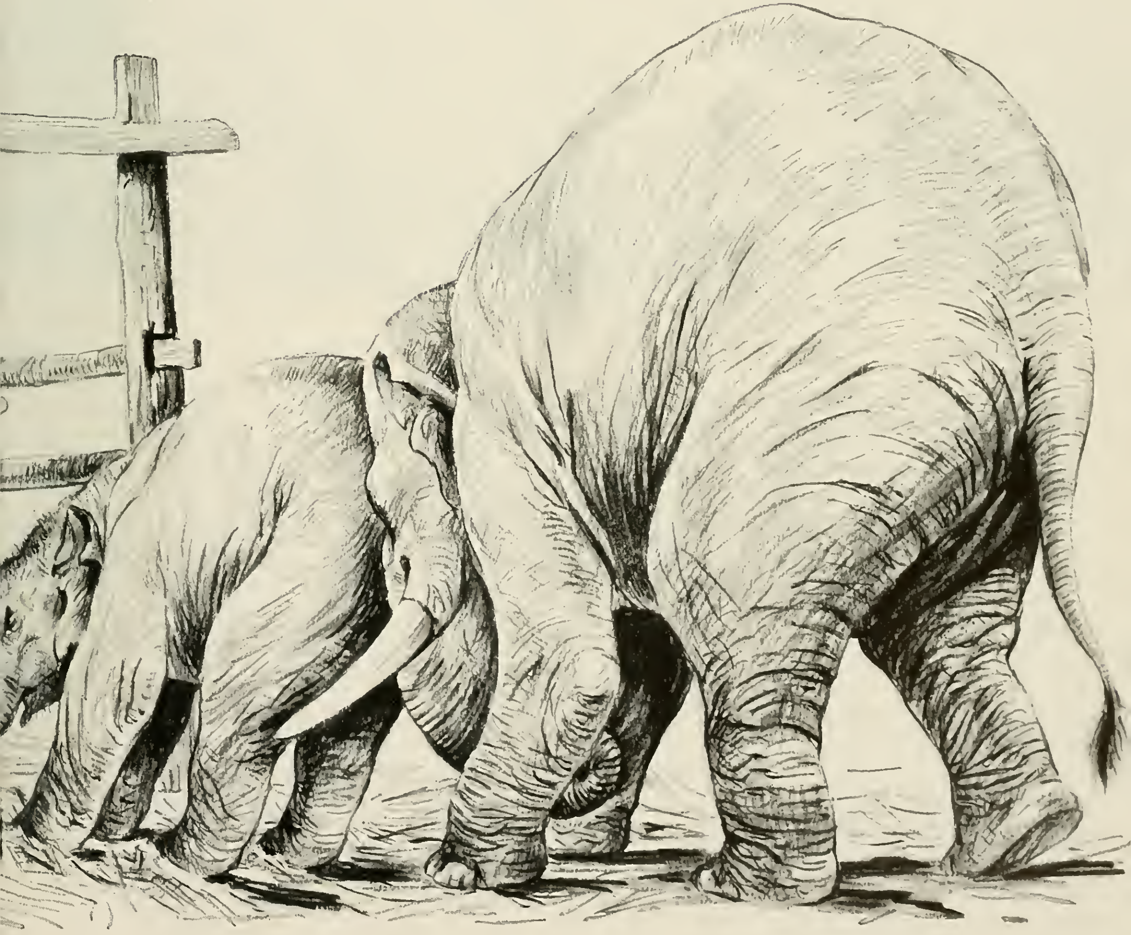
tall as a man, and he stood huddled—sulky-looking—with his head down. His trunk fell straight to the ground, where its end was tightly coiled, and the ground itself was muddy from his standing there. Each front ankle had a rope round it; the right one had a chain, as well, which went up past his shoulder to the crush's top. His back ankles were hobbled and hitched to a post. Round his neck, behind the big ears, was tied a rope that led to a post in front of the crush, apart from the main structure: under him was stretched a girthlike sling. He could not kneel, or pull back or really move at all, although he tried to now and then, shaking the posts of the crush.

The female, smaller, had been taken out of her crush when we arrived. She stood beside it, her neck in a stanchion made by sinking a fifth post next one of the others, and her midriff tied by a woven girth to the crush's side. She, too, was hobbled. She had more leeway than the male, but used it less. She stood quietly while one of the trainer's helpers stepped on and off her neck from the top of the crush, getting her used to this action.

DESPITE his more confined bondage, the male looked better than the female—his dark little eyes were brighter and he seemed more spirited. The trainer came over to him now: a man of the slight South Asian build—long, delicate hands and long eyes, a brown skin and full lips we might call sensuous. He wore lose cotton clothes, and a towel round his head like a turban. He climbed the crush and put a foot on the male's head, right at the crown. He pressed his foot down a few times, and the elephant strained against the crush, but fruitlessly. Then the trainer moved onto the male's head and neck and stayed there, squatting on his heels. He squatted, eyes half-shut, as if settled for the day.

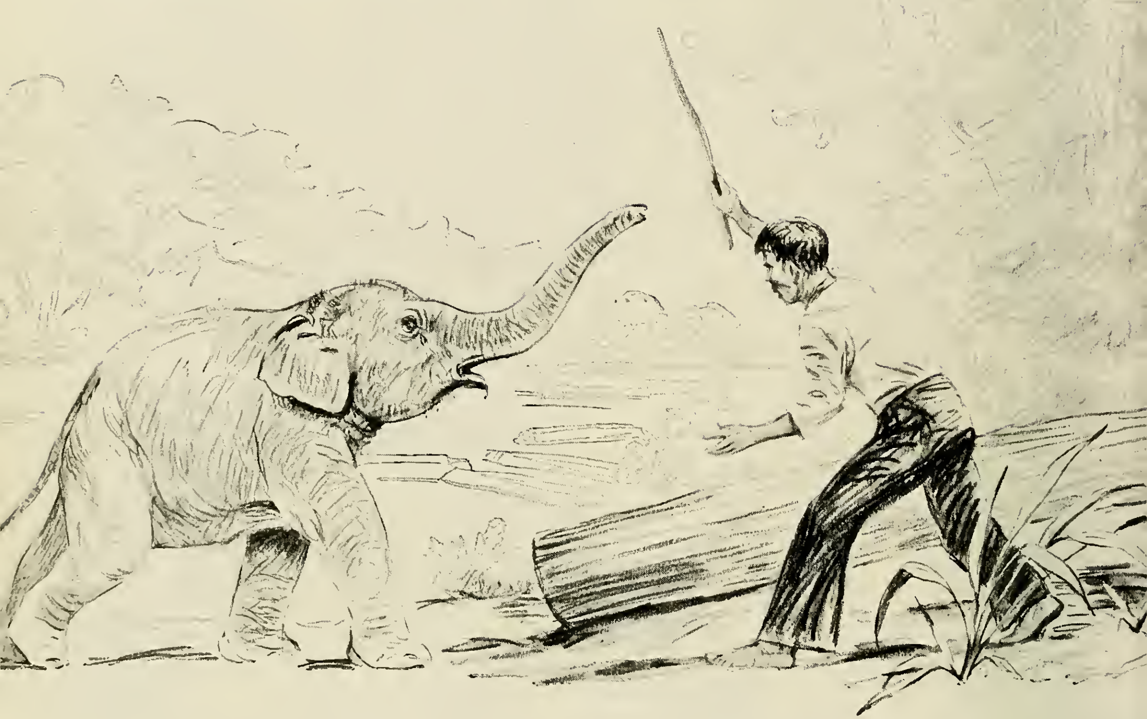
We seated ourselves on the ground nearby, and began talking. I learned that the trainer was almost forty, although he looked younger. One of my companions held a banana toward the caged male and his trunk snaked out and seized it neatly, coiling back at once to stuff it in his mouth. We went on talking with the trainer. Both elephants, we learned, had been put in their crushes a week earlier—the female had been coaxed in easily, but the male had fought and, in the end, a big tusker had been brought up to push him. The little male had been standing there, facing the broad, open end of the crush, and balking. The big one had put his tusks under the calf's rear end and shoved him in before he knew it: the men had quickly fixed logs across the opening.

This initial struggle had set the tone



Illustrations by MATTHEW KALMENOFF

Tearful baby elephant splashes across a stream, tries frantically to reach its hard-working mother. Despite beatings, it refuses to be driven off.

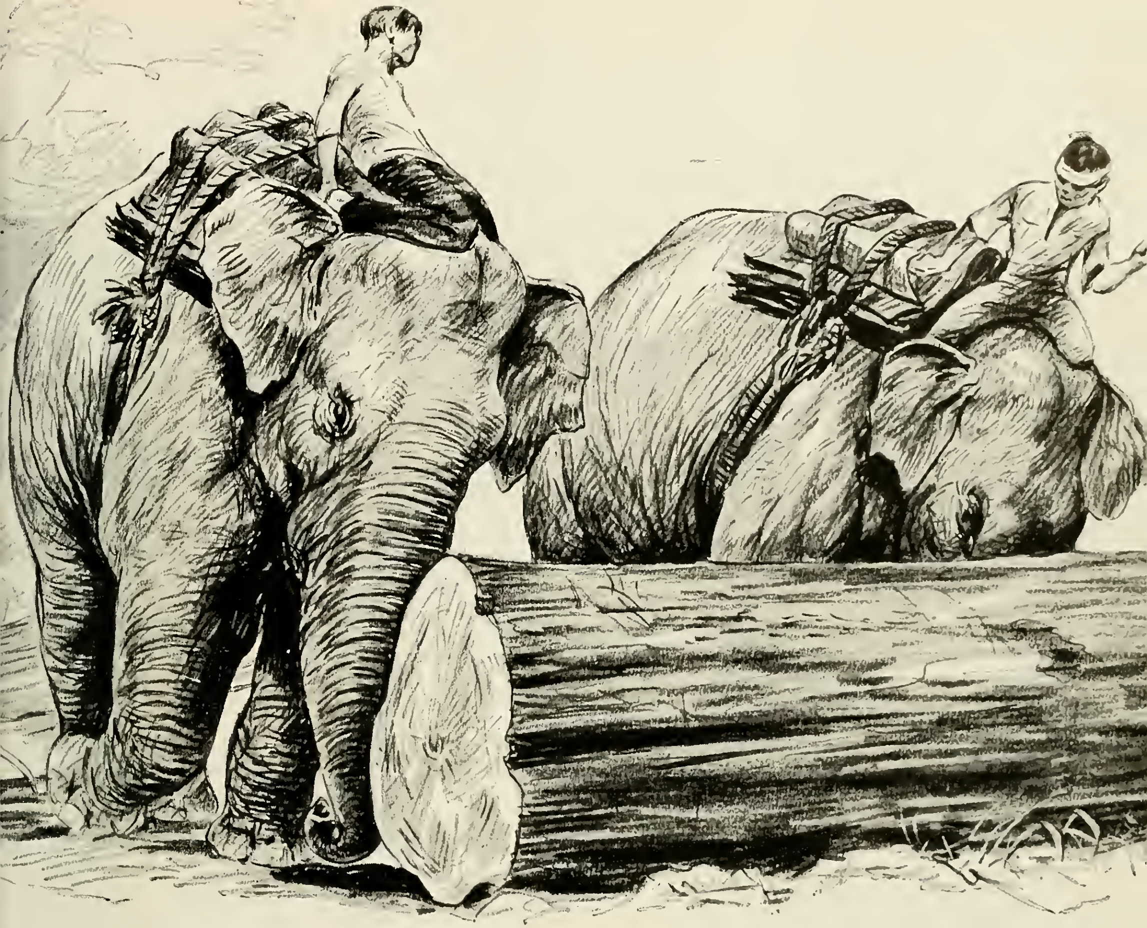


of the young male's training: "He fought back," my companions said, "so the trainers have been rougher with him: and so he keeps fighting, and he may never really be gentle." The trainer told us the male was three-and-a-half years old and the female four. They were both offspring of working mothers of the Borneo Company. The female calf was learning much the faster—she had been out of her crush for a day, having been in it, during lessons, for six days before.

SUDDENLY, as we talked, the little male threw the trainer off. I did not see it but, all at once, the trainer was sitting on the ground. He got up and took a metal hook that lay there, with roughhewn handle, and with its point he struck the base of the elephant's trunk—once, twice, three times—quietly and seemingly without emotion. The elephant pulled back and roared, and again he sounded like a tiger, but also like a squealing pig. He roared and roared, and he pulled so hard that he uprooted the post his neck-rope was tied to. He tired of the struggle and calmed down, and a helper cut some lengths of vine and patched the crush. There was no lack of vines here, or of other jungle materials; almost the whole establishment had been hacked out from them, and spare parts were cut as needed. Little had come from the outside but chains, rope, and tool blades.

The trainer had three or four such helpers. They brought green forage from the jungle and taught the elephants minor things, like raising their feet for hobbling. One would put a creeper hoop next to a foot and say "*yoke*," meaning "lift." If nothing happened, another helper would prod the foot with a goad; up it would go, and the hoop would be slipped on the ankle. The elephant could not see the hoop, which made it hard. The helpers worked away at one thing after another, keeping up the pressure. They had two goads—sharp nails in the ends of poles—and one real spear, and they used the goads now and then, sometimes producing roars from the calves. The elephants bore marks from this, and marks on their legs as well, from the hobbles.

The helpers were plainly just manpower, however. The trainer himself was the expert. He had learned the art from his father, he told us, and I



gathered there was magic in it, along with the obvious things—magic, for instance, in parting mother and calf.

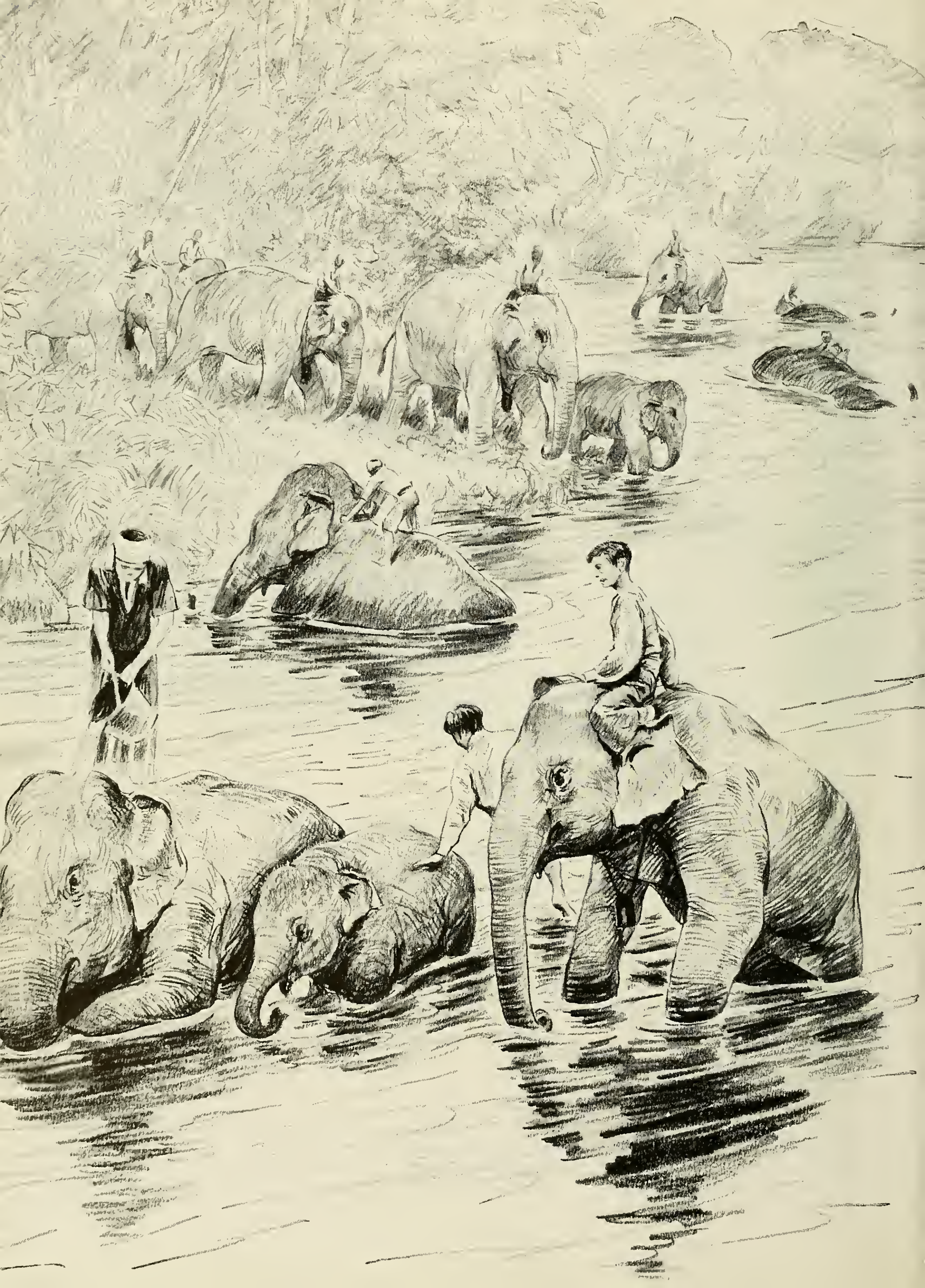
There was tradition, as well. When the male had been put in the crush, for example, his tusks had been sawed off near their points—losing two inches, say, from eight or ten—so that they now were blunt. I learned later there are good reasons for this practice—the cutting makes the tusks grow stronger, as pruning does the tree, and also lessens the risk of damage in the crush. But when we asked the trainer about it, he merely said it was the custom, and I felt he meant this, and was not just showing impatience with my questions.

The clearing was as big as a tennis court, but irregular and shady. The path ran by its edge. People came along, and stopped and squatted to watch, and then went on. At one time there were a dozen there. One was playing a flute. Two others were Buddhist monks, dressed in gold-orange robes and holding parasols of a peculiar red, leaning to caramel.

THE time wore on to noon, and the trainer spoke to his helpers. "They will take the elephants out now," my companions said. "The day's lesson is over." The helpers untied the female and led her, hobbled, to a stake in the clearing. They moored her there and put a big stack of leafy branches before her. She stood quietly, picking the branches up, stuffing them in her mouth, and munching them. She could devour an inch-thick branch with ease and apparent pleasure.

They began untying the male and letting him out slowly, tightly hobbled. The trainer guided him with the spear, while one helper paid out the neck-rope and another got the chain round a stake. They inched him along. Then suddenly the calf sat down—whether from intent I could not tell—and stayed there still struggling, although looking solemn, and rumbling gaseously at both ends. He went over flat on his side, like a horse when cast, and the trainer and a helper went to his back and pushed him, saying "*look*"—"get up." And get up he did, for all his bonds, and was edged over to his stake, and fed. He, too, stood there quietly, but pegged down tight from two directions, while the crew lighted a fire and began cooking lunch.

Two weeks later, I visited the same



elephants with Dick Wood, the Borneo Company head for North Siam, who went to inspect them. A well-set-up man, heavyish, with sandy hair, Wood had entered the teak business in Burma when he left the University. Now he had switched to Siam because, as he said, Burma was in a mess. He wore khakis and heavy boots, and carried a cane. We did not have so far to go as on my first visit, for the elephants had been moved closer to Chiengmai—the crushes left behind.

We came on the pair just beyond a village. The male was tied to a tree and to a stake behind, and hobbled. He had grown noticeably, I thought, and Wood did, too. "He is very big for his age," he added. "He will probably go eight feet and more, though you never can quite tell." He looked him over, and said his front feet seemed infected. "They had to keep him in the crush a long time," he explained. "It looks as if his feet were septic from standing there." But he thought the back legs were all right, despite some chafing. "It could be worse," he said. "You often find grown elephants with great white scars on their back legs. You cannot do much about it if they struggle in the crush." He lighted his pipe. "We will have him off and watch him walk."

He spoke to the trainer, and the elephant was untied and led along—hobbled and guarded with the spear. Wood thought him a bit sore. A helper climbed up astride the elephant's neck, but backward, clasping a girth of cane round his middle. The elephant roared, and buckled clumsily in his hobbles, and the helper got down fast. "He's still too wild for that," Wood said. "But they can make him go where they want. He's got to the stage where, without actually being stuck by spears, each stick is a spear. He's got his reflexes straightened out."

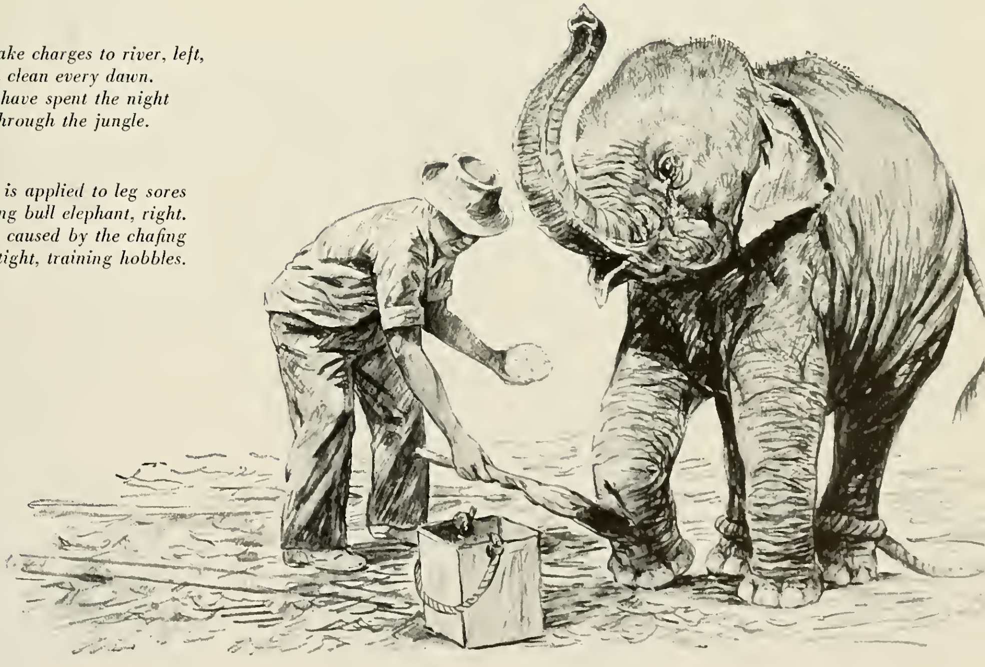
He turned to the female while the male was tethered again. I saw she wore a bell now, a hollow cylinder of teak, as big as a quart can, with two teak clappers at the sides—it made a tocking sound when she moved. She had a swelling on her trunk, which Wood thought might be emotional, but she walked out easily and gave no trouble when ridden. I felt the trainer must be nearly through with her, and I asked Wood about this. "No," he said, "she hasn't got the tricks yet." But she was docile as they tied her up. She stood on short green grass, while two red-and-black gamecocks from the village picked about nearby.

The trainer got after the male's leg sores. "Absolute rogue, this trainer," Wood said to me. "He's been with us for years. He's one of the few left who've got the sort of elephant lore to them. It's half rather good, and half sort of mumbo-jumbo. He knows things no European will ever know." A helper brought a kerosene tin filled with pieces of red bark in a liquid, and the trainer sloshed this on the legs with a cloth on a bamboo handle. "That's as good as any modern antiseptic," Wood said. "But then, half their things are old wives' tales. They think spiders and ground glass are good for the eye—if there is something in the eye, they reason, you make it water and wash it out. But then you've got an inflamed eye."

The bark solution was red, and warm when I put my finger in it; and they smeared on a red paste too, from a bamboo tube, which I gathered was from the same tree. The elephant leaned forward when he felt this, straining against his bonds. "I suspect it stings," Wood said. He asked me to remind him about sending out an ointment to help keep the flies off, and I asked if newer Western methods had changed the handling of elephants much. "Yes, it has," he answered. "Take this elephant. You have to say,

Mahouts take charges to river, left, slosh them clean every dawn. Elephants have spent the night foraging through the jungle.

Antiseptic is applied to leg sores on young bull elephant, right. They were caused by the chafing of tight, training hobbles.



'don't leave him in the same place every day, or he'll get sore feet.' This chap might think every one gets sore feet and gets over it."

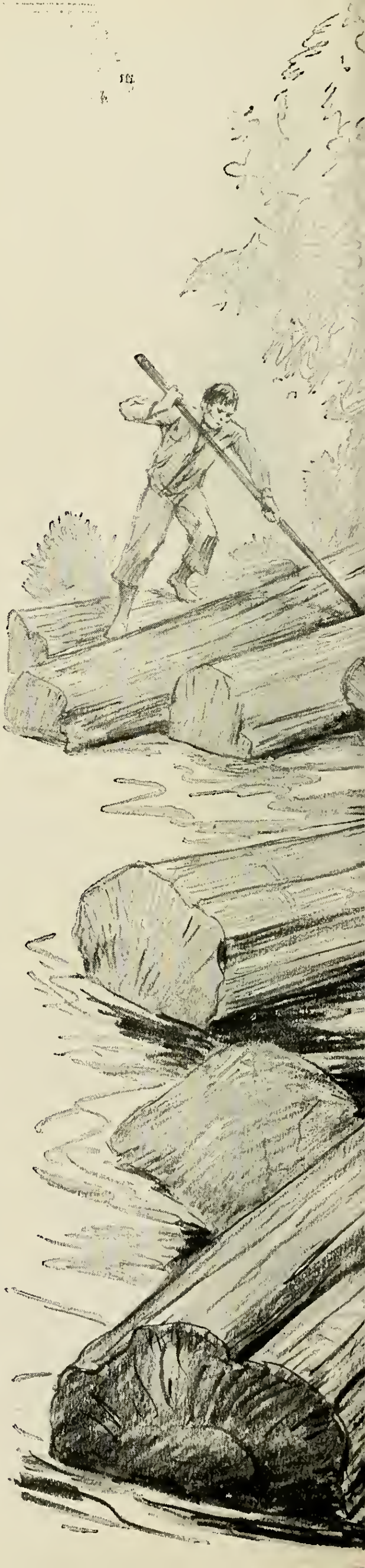
Wood told me that using elephants in work—as in war and ceremony—was largely an Asian art, begun in India and brought to Siam through Burma. The words of command spoken to elephants round Chiengmai were chiefly Burmese words. When the British had taken Burma, they had taken over the elephant business, too. They financed big companies, organized a world teak market and applied their ideas of maintenance to the elephants themselves—insisting they be not overworked, or worked at all when young. If these two calves could stay in British hands, he said, they would have fifteen years of idleness ahead: following older elephants round, and being ridden a little and taught things. Then, near the end of the apprenticeship, they would carry light baggage on trips—elephants do some ten miles daily when used as pack animals. But the Borneo Company would let them go, for the future was too unsure for long investments. When trained, both would be swapped to a Siamese for a grown tusker, usable at once. The training itself, Wood said, was costing a thousand Siamese ticals—fifty American dollars—for the pair.

I asked about the elephants' conformation as they stood there munching leaves—thanks to their trunks, of course, they ate without the distortion of lowering their heads. Wood liked the male a lot, and spoke of his massive backside and little short back legs, a good setup for pulling, I gathered. "Back straight," he said. "Trunk thick. He's got a heavy head, too, not one of those lizard heads." The elephant's forehead bulged out strongly before the eyes, and the line dropped straight from there down the trunk. "Then he has a long tail and good brush," Wood added, pointing to a fringe of black hairs round the tail's flat end. "They seem to think it's a good thing. I don't know about that. It seems to me absurd, but there you are." Wood did not care much for the female—he thought her head too long and her back legs the same. "She must have some fault," he said. "Her ancestry is not all that good." Elephants mated at night, in secret, he explained, but they went through enough preliminary courtship so that the mahouts could usually keep track of pairs. In the old days, Wood told me as we walked back, one could follow them from generation to generation, as well as from babyhood to prime, but this was true no longer. "I'd like to see this male when grown," Wood said, "but I doubt if I shall."

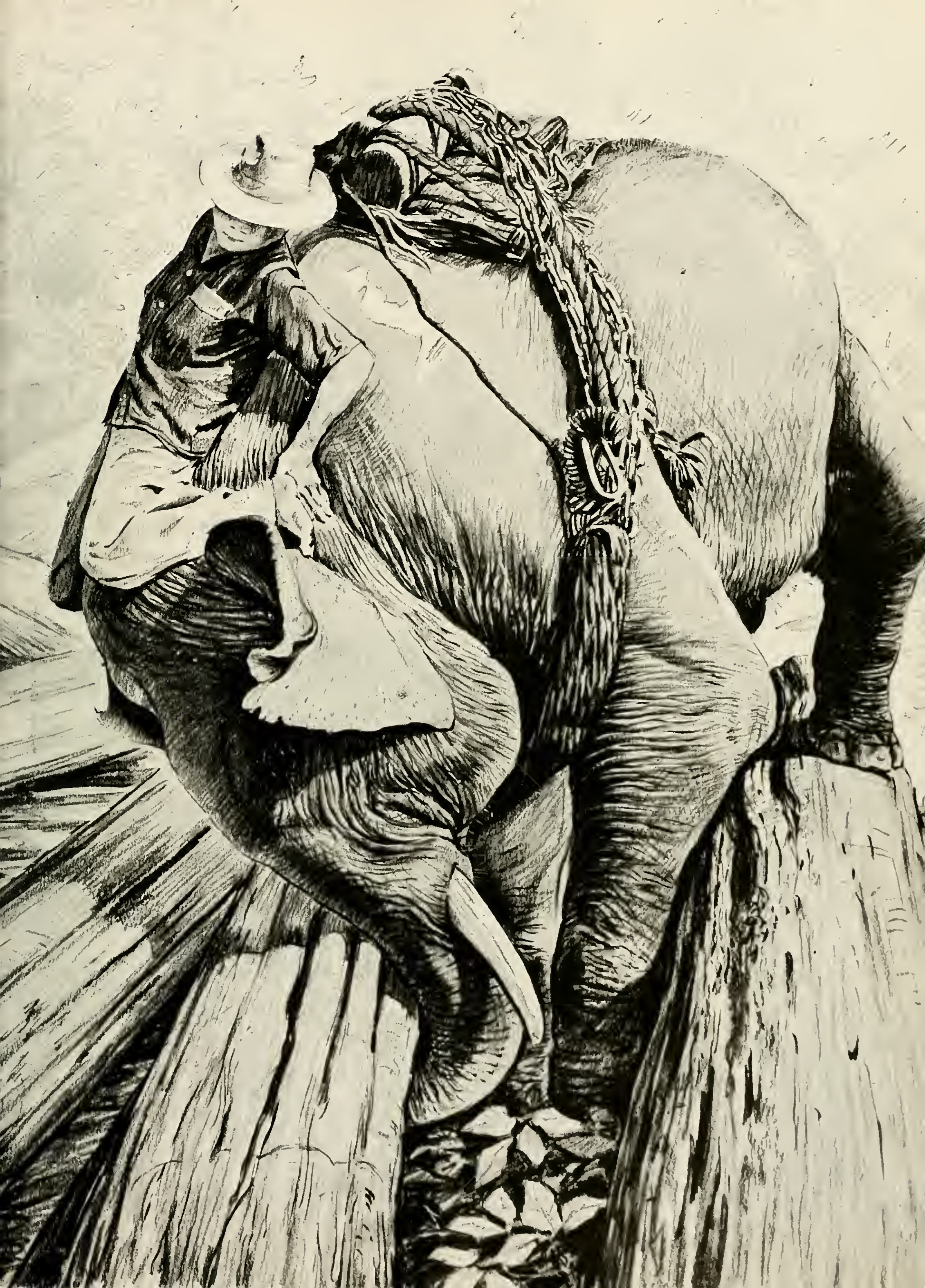
Some time later, I visited a Borneo Company station at a place called Fai Lor, where great teak logs were being hauled out of the river, to avoid hurting a set of dams, and trucked overland a few score miles to be put into the river again downstream. Teak is a hard wood, and durable. It has a grain and a natural smoothness that make it desirable for furniture. But the teak business is slow. Each log takes years in the journey from forest to market. Two years are needed before a log will float at all. Then it is slipped, with the owner's marks on it, into a small stream, and finds its way, perhaps years later, to a river. There, it will be rafted with others to a port. The streams have to be policed, of course, or the logs would be stolen: Burma was not doing this policing then, so Siam had the business. Siam had shipped two hundred thousand teak logs in a recent year, each log averaging nearly a ton, and these were boom figures for her.

The elephants working at Fai Lor were off the job when I arrived about sunset—they had been turned loose at noon, as is the custom, to forage in the jungle until the next morning. The headman, a Chinese named Tong Yin, gave me a shelter for my cot and mosquito net—a palm-leaf hut with raised bamboo floor.

The jungle was still during the night, the hoots and cackles not beginning until near dawn, which came just after six. I was up then, and went to some outlying camps on the riverside, where the mahouts lived and kept the elephant harnesses. I stood on the bank in the half-dark, and soon a mahout rode out of the jungle across the river, his elephant's bell tocking. He rode into the water. The elephant lay down, and another man came with



Trunk and tusks together move one-ton teak log. In this maneuver, called "aung," elephant uses foot to prevent the log from rolling backward again.

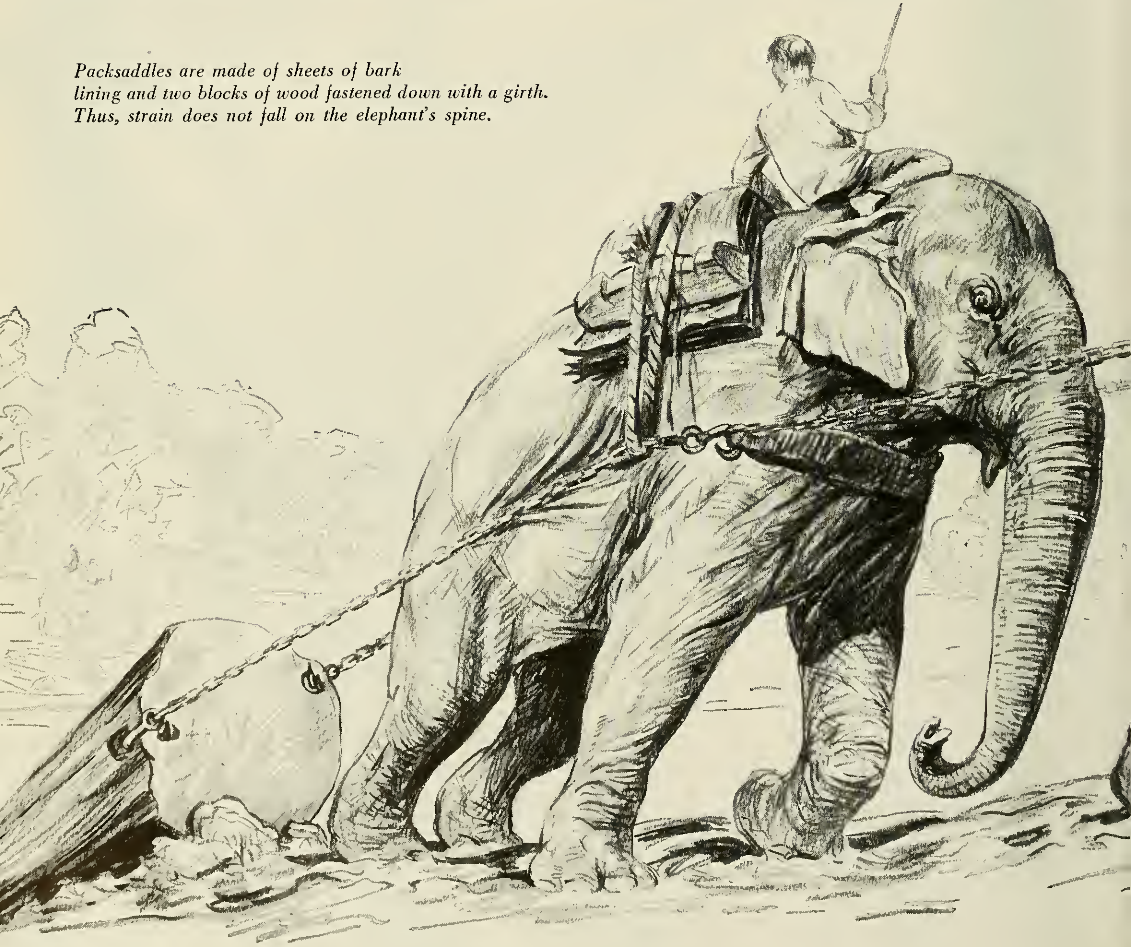


a pail; the two began sloshing water all over the elephant, turning its color from pale to dark in the dawn light. Other mahouts rode up as I stood there—having tracked and caught their elephants—and they began washing them too. It was chilly and I was glad to wear a sweater, but the elephants seemed to enjoy themselves.

There were eight of them now, in the stream on both sides. The first one rose and crossed to a tree beside me that held harnesses in its branches—about eight feet above the ground. Its mahouts began putting one on. There were six or eight pads, made from sheets of brown bark-lining—the size of an opened newspaper, perhaps—and he stacked these on the elephant's back where a saddle would go, making a pile several inches thick. Next, he took two chunks of wood—as big as fireplace logs—tied parallel, a foot apart. He put these on the pads, so they lay on either side of the spine, and fastened them down with a girth that the elephant stepped into, at his command. when he took it from the tree and dropped it to the ground. He stood on the blocks of wood and tightened the girth, making a packsaddle from which he hung breastplate and traces. so these bore not on the spine but on the wood blocks and, through them, on the bark. Thus, the weight was padded against rubbing.

It was seven now, and full daylight. The mahout got down and went into his hut for breakfast. I went for breakfast too and, when I came back, the elephants were working. A tusker and a cow were stacking logs so they could be loaded on trucks and trailers by a small derrick. They made neat piles of six logs—three at the bottom, then two on these, then one at the top. They seemed to know what they were about. One elephant would get under each end of the log, and then the pair would shove upward—a movement that needed teamwork, because no log would go evenly. One end would always get ahead, and have to be held while the other caught up. Then, too, most of the logs were irregular and awkward to handle. When the elephants began putting the top log on a pile they almost knelt to get under it and get a proper start. When each log was in place, the tusker would nudge it lengthwise until the pile's ends were trim. The mahouts bossed the work, but the elephants understood it.

Other elephants—half a dozen of them—were pulling logs from the waterside to this pair of loaders. Two of the pullers were hitched in tandem, and they had teamwork also. The mahouts would urge them on, bouncing on necks and scratching ears with toes, but the two elephants would disregard these directions until ready by some timing of their own. Then, they would hit their traces together, and

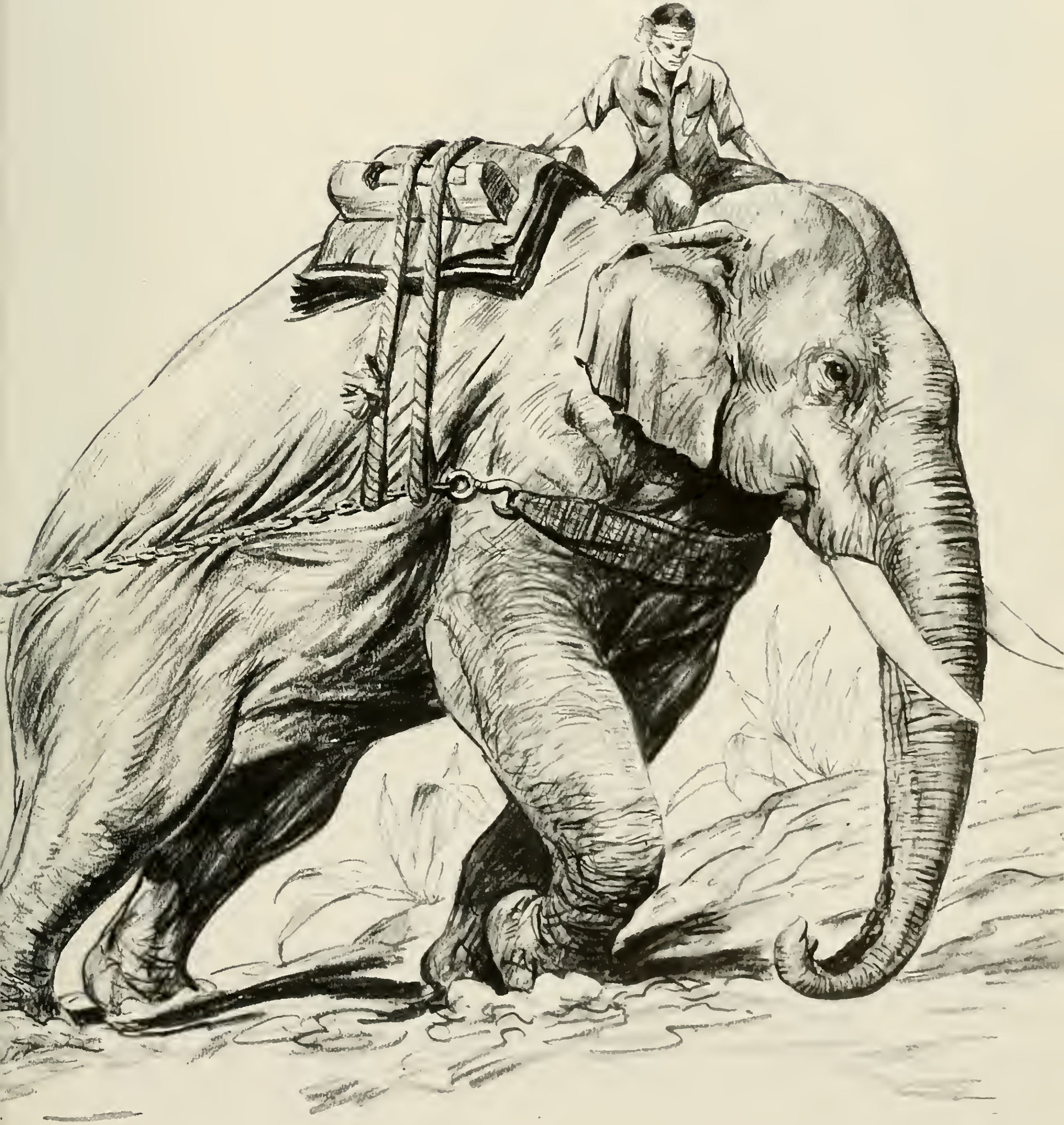


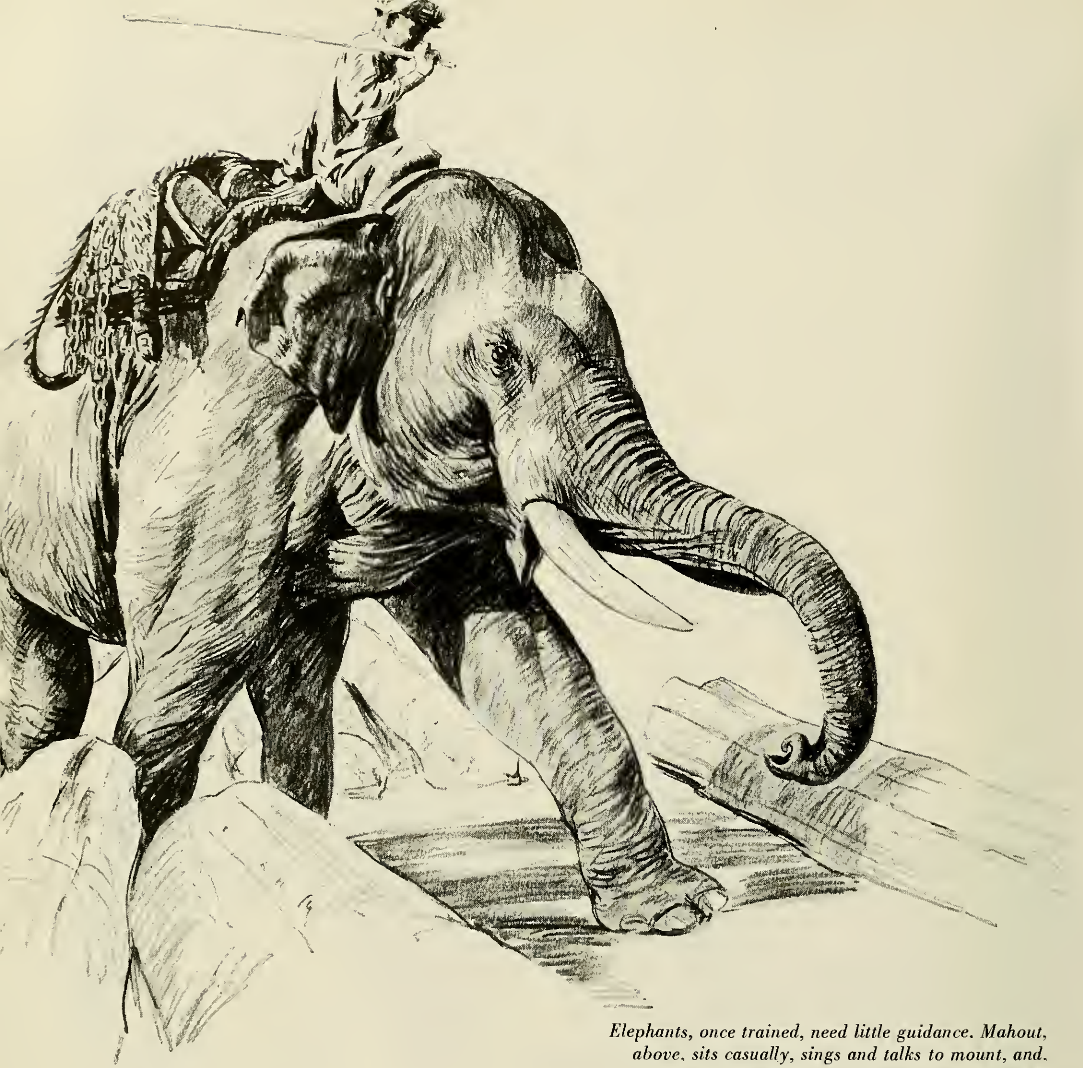
Packsaddles are made of sheets of bark lining and two blocks of wood fastened down with a girth. Thus, strain does not fall on the elephant's spine.

they moved big logs—a ton or more in weight—that way.

The elephants differed much in size and capacity. Some were small cows, used only on the spindlier logs. One was a big tusker. He seemed well built: short hind legs and massive bulk; the crown of his head came forward, the line dropping straight down his trunk from there except for the bulge near his eyes. He moved the biggest logs without complaint and helped when other elephants got stuck.

While standing there, I heard bellows from the jungle across the stream. and one elephant near me bellowed in return. Soon, a calf appeared on the facing bank, smaller than the two I had watched in the crushes, and it bellowed with amazing deepness. The elephant near me—I saw now it was the mother—bellowed back. The little one roared and squealed, and ran back and forth on the bank with its trunk extended straight ahead. The mother turned toward it from her work, distracted. Then the baby splashed across to our side, and some men on foot—there were a number of them about, hitch-





Elephants, once trained, need little guidance. Mahout, above, sits casually, sings and talks to mount, and, right, grips saddle rope to keep from sliding off.

ing chains to logs—threw stones and drove it off. It kept returning. Once, a man jabbed a stick in its rump: it cried "YURP!" and jumped away. But it did not go far. It hung about all morning, getting underfoot and trying to nurse its mother.

THE mahouts jiggled a lot as they sat on the elephants' necks. That was one way to egg their charges on, along with words and digging toes in ears. Each mahout sat on the neck, the elephant's shoulders and the log saddle behind him. He could sit cross-legged—tailor-fashion—or sidewise or astride, or he could recline against the saddle. A frequent pose was to hang one leg down by the elephant's neck and double the other up forward, hooking the knee on the crown. When an elephant put its head down to push a log on the ground—a maneuver called "*aung*"—the mahout would hold on to a rope anchored to the saddle to keep from sliding off.

The mahouts were all slight, barefoot, and dressed in the casual, pajama style of these hills. They were idle much of the time: they smoked cheroots, spat, sang and talked to their elephants. One leaned forward and lay on his elephant's head, reaching down with a stick and playing with its tusks while he chatted to it in falsetto. The elephants snatched branches and ate when they could, and they walked back and forth peacefully, bending their front legs at their low knees—like the knees of hopelessly baggy trousers—and putting their feet down softly.

At midmorning, the elephants moved into the water and began hauling more logs ashore from a point upstream. They were in above their knees, and the water gurgled and washed as they moved through it. They kept the ends of their trunks out of the water, I noticed, holding them in their mouths or draping them over their tusks, as a woman might drape her shawl over an arm. The current was fast in one place, and some elephants trotted there to keep ahead of the logs they pulled. They dragged them ashore and then up the bank, straining against the obstructing mud.

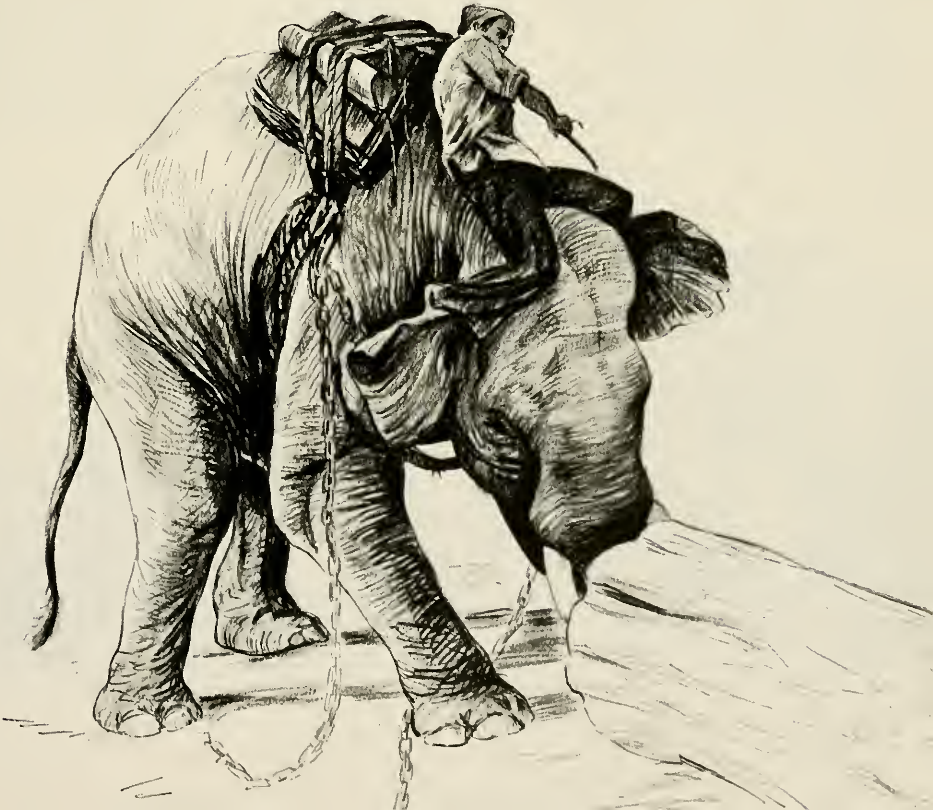
THE sun grew brighter and the tusks flashed white in it, and at half-past eleven they were ridden ashore, unharnessed and belled again, the mahouts getting down. Then each elephant raised a front leg and the mahouts climbed up, and rode off bareback into the jungle, to leave them there. I watched three broad-beamed elephants walk away together, ears flapping, tails swinging, and bells tocking. It was noon by then, and the light was glary and tiresome.

I also had occasion to see the return of teak logs to the river after a trip by truck—and to view a "problem" elephant at work. This was at Tah Tarn, a Borneo Company station below Chiengmai. The man in charge there, Mr. St. Amory, led me to where the "bad character" was at his work, pushing logs off a truck and trailer that had come to the station the previous evening. The massive bull butted the logs with his head or, sometimes, his tusks and trunk. Pretty soon, he had them on the ground. A spearman stood by him as he worked, and another was in the offing. St. Amory told me that this same bull had killed five men in the past. Only a few weeks earlier, he had smashed up a boat and his mahout was the highest-paid hand on the place.

The elephant was in his prime—his middle thirties—and he looked eight feet tall to me, and strong. The river bank where the trucks drove up was flat and dusty, and he walked on it silently but for the clinking of his chains. He raised his feet only three inches off the ground and put them down softly. His tracks were bigger than pies; the front ones broad and the hind ones, placed on them, narrower. Round about the unloading area was a sea of teak logs, pale grayish-tan, stripped of their bark and beveled at the ends for dragging. The elephant was tidying these, clearing a way through them and pushing some to the bank's edge.

AT times he got his tusks under a log, with his trunk coiled out of the way—tight, like a snail. Or, he pushed with the trunk itself. Or, if the log was small, he might roll it with trunk and tusks both, using a front foot as well, to steady it from rolling back between shoves. The log would spin along merrily. The mahout sat on the elephant's neck, guiding it by words and by poking the backs of its ears with his toes. But the elephant himself figured out much of the work.

With small logs, he used his body but little—slipping his tusks under them and tossing his neck. With big ones, he threw in everything. I saw him roll, without much trouble, a log that St. Amory said would go a



ton and a half. And it was awkward, more flat than round. Several were that way, or were curved, so that the bull needed trunk, tusks, and front foot to keep them from rolling back. He managed deftly and quietly, and could skid a big log endwise by nudging his tusks against its base.

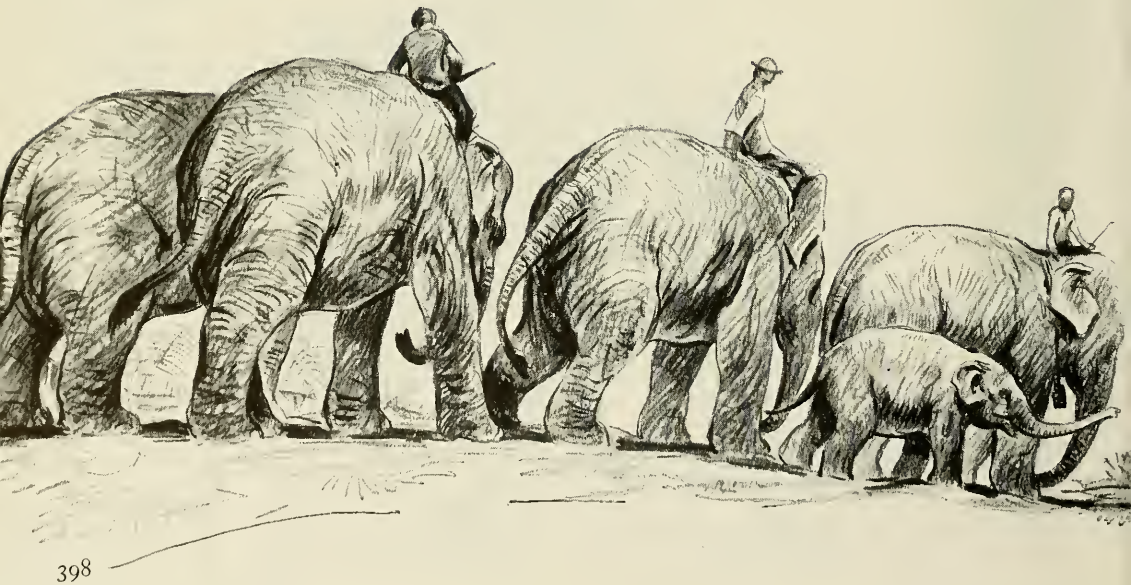
In time, the new-brought logs were pushed aside. The mahout got down, the spearmen closing in as he did so. The mahout took the elephant to a big, rather orderly stack of logs and began the work of dragging these to the edge of the river bank, hitching the elephant's chain traces through a hole that had been cut in each log's end. The elephant was hitched to a medium-sized log and he dragged it briskly across the dust—so fast and freely that a few onlookers, lounging nearby, got up and ran away, knowing his record. Then he was hitched to a bigger log, and he plodded along more slowly, shaking his head. When he got a log to the brink, he was unhitched and then he pushed it off so that it rolled down toward the water. Often, he pushed with his trunk and a front foot together, kicking them up, in following-through, like chorus girls' legs. The later logs resounded as they hit the earlier ones.

After each log was pushed off, the elephant turned and followed the men back to the pile. He was ponderous, deliberate, silent. From the rear, he looked wide and bulgy, with a huge, thick spine: from the front, he looked more vertical, chiefly because of his trunk, which hung straight to the ground, with half a foot to spare, curled up like the end of a vine. Once the men hitched him to a big log that was under others in the pile—hard to start—and he roared and squealed. But he squatted and heaved into the traces, and got it going. I saw what Wood had meant about short legs and massive backside.

Soon the bull had moved half the stack of teak logs over and shoved the logs over the edge of the bank, where they lay higgledy-piggledy in the shallows. The mahout mounted him again, climbing up by the breastplate, and rode slowly down the bank. The elephant slid part way, with front feet set together, then stepped into the river and began spraying water on his chest and sides, using his trunk like an atomizer. Then he sprayed his belly. He drank, looping his trunk back to his mouth. He went in deeper and stayed there awhile, snorting and splashing. Then he moved gingerly up from the deeper water to the log pile, and began taking it apart, pawing the logs and nosing them with his trunk. Out in the stream a long boom had been rigged—a floating fence of logs—for many logs were being gathered and held there, to be sent down river when the rains came. They lay rafted loosely offshore, with a stretch of mud-brown water between, and the elephant scooted the fresh logs out to join them, kicking them as a boy might kick toy boats out into a pond. He took his time, while the mahout sat on his neck and the spearmen stood idly by. Once the men spied a lizard on a log, drifting in the river. One of the spearmen tried several times to hit it with a slingshot. All hands stopped to watch him, engrossed, but he kept missing, and the lizard passed from range. The problem elephant worked on till noon, when it was hot and glaring, and then he was ridden away.

Formerly correspondent for the N.Y. Herald Tribune, and author of five books, Mr. Rand regularly contributes to The New Yorker, and is now in the Middle East for that magazine.

My elephant study ended with another session with Dick Wood. He took me for a picnic lunch one day, while he looked at teak near Chiengmai. It was cool weather, sunny and bright. We sat by a path on a hill and were eating our sandwiches when a long file of elephants came past, dragging logs up the slope. They belonged to a local contractor, and Wood frowned on the way the man was working them. Wood pointed out that rollers should be put under the



logs on the grade and that the path should be banked, so the logs would not slide off on the curves.

"It's bad work," he said. "They're making money, but they've got no long-term thing at all." Half the elephants were too young for use. he thought. "Wretched little tusks." he said of one. "Spots on his belly. Probably eighteen. Been working for ten years, I should guess." But others he thought all right. "A damn nice elephant," he said as a big cow walked by. "She's about forty, in her prime. Look at the height of her."

"How can you tell she is forty?" I asked. "She *is* forty, that's all," Wood replied: "bet you she's between forty and forty-five." I did not take him up. I watched the elephants come past, the hard logs singing a bit on the hard ground. I asked about the basic things elephants were taught, and Wood said these were dragging, pushing or *aunging*, kneeling, picking up things, and pulling branches out of a rider's way when traveling. He said they were clever at this last, and in Burma in the old days. on a cool evening, they would pick up dry branches and lay a fire for you. I spoke of how neatly the two elephants had stacked the logs at Fai Lor, and asked if they all knew about sliding them that way, to line the ends up. "Yes, they do, after a while," he said. "They're far from stupid. They know just what, after a bit." He ate a sandwich. "They're unlike mules in that they don't forget," he went on. "I don't mean 'an elephant never forgets' in the usual sense. But if you teach a mule something, you are supposed to have to teach him again the next day. That isn't true with elephants."

I ASKED what an elephant's most striking talents were. He said that walking on slippery ground was one, the kind of ground where a man could barely move with hobnailed boots—elephants gripped on to such places like an octopus. Then. they were good at untangling log jams. They would go out into a stream, groping along the bottom with their trunks, and would sense what log was holding the jam up. "You find the elephant fiddling around," he said, "and suddenly the whole stack begins to move. A human can't do that, but an elephant knows just how to go about it. And it's a dangerous job."

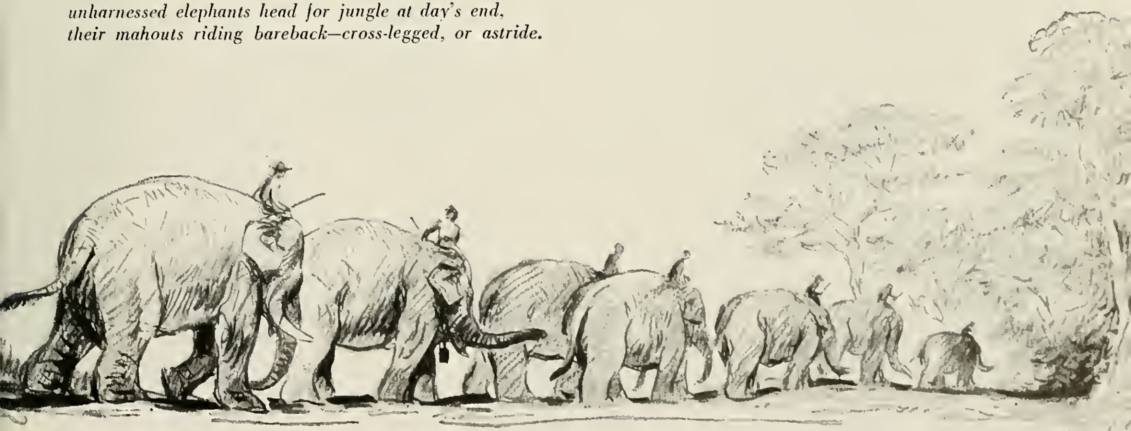
The elephants walked slowly by on the hill path before us. each with a mahout on its neck, killing time or jiggling. "They love their elephants," Wood said. "They live with them all their life. But they don't know how to treat them. Their minds are primitive or single-track. So they don't put rollers on the drag paths, and they work their elephants too young."

Wood believed that Siamese from the towns could be taught better elephant management, but they wouldn't stick the jungle life. It was the same with machinery. Much of the teak logging could be done with tractors, but the Karens—who were adjusted to jungle living—couldn't be taught to keep the machines up. You could bring Siamese mechanics in to do the maintenance, but they would take one look at the jungle and go home.

Wood talked on about the Karens and Siamese, and about the Burmese, among whom he had lived for years. He thought the Siamese were "gray" in character compared to the Burmese. who were either "black" or "white." "If they've got a bad character, the Burmese, they've got a pile of it," he said. But he said it with no distaste. and he spoke at length of the Burmese and their country. I felt he applied the same detached intelligence to Burmese, Siamese, Karens and elephants alike. and I reflected that his nation as a whole had done this. and fruitfully, for no one else in history had ordered teak, Asiatics, and elephants to such effect. I didn't speak of this, though, or of whether that period was finished.

I watched the end of the parade go by. The last elephant was a big one, and its tail kept swinging as it walked away. "That's a good sign," Wood said. "If their ears flap, tails switch and trunks keep moving, it means they're in good condition." Tail aswing, the elephant vanished among the trees and we packed up and left.

Bells tocking, ears flapping, and tail swinging, unharnessed elephants head for jungle at day's end, their mahouts riding bareback—cross-legged, or astride.



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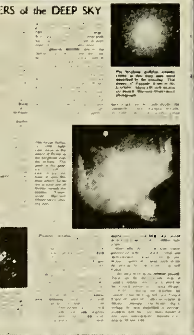
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SKY REPORTER

By Henry M. Neely

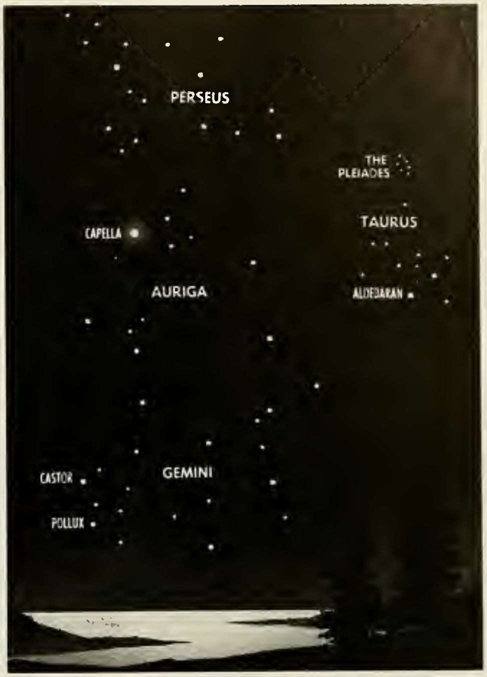
An almost continuous display of meteors appears in August's night sky. This year, the moon will not interfere — during the first half of the month — with those who watch for meteors between midnight and dawn. Most brilliant and reliable of these meteor displays are the Perseids. The first stragglers will have appeared in late July: the shower reaches its maximum between August 10 and 13. The Perseids' radiant — or point of origin in the sky — is shown on the chart, *right.* Face a little north of east and the brilliant star, Capella, cannot be missed. The radiant is just above that star.

The Delta Aquarids constitute another display that began in July and will continue until August 7. The next chart, *below*, shows their radiant. Again, there is a first-magnitude star, Fomalhaut, to help locate the area. Nearby in the sky are the fairly bright stars Algiedi and Dabih in the constellation Capricornus, which mark the radiant of a third shower, the Capricornids. This also began in July and will continue until August 22.

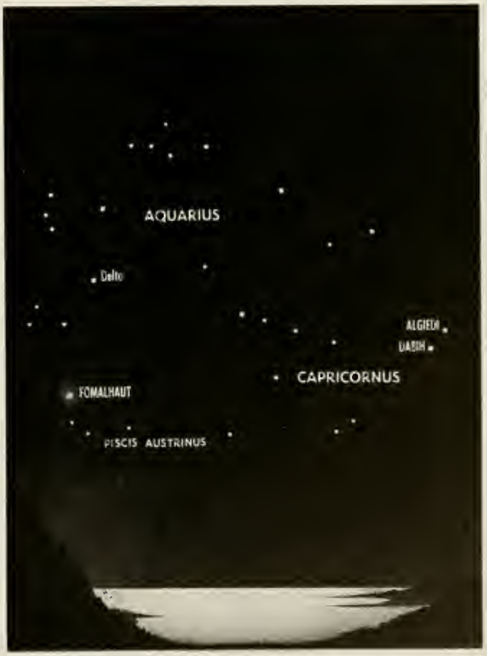
From August 10 to 20, a mild but interesting shower comes from the region of the star Kappa, in Cygnus, (shown on the August roll-around map, next page, near bright Eltanin — almost overhead when facing north). Brilliant Vega marks this area unmistakably. At the time the moon permits viewing — 4:30 a.m. — Vega will have moved more than halfway down the sky, over the northwest. The radiant for the Kappa Cygnids is above Vega.

Our neighboring planets will undergo a decided shift in their positions during August and September. Mercury appears as a morning star in the east as dawn begins on August 23. Observers along the Canadian border and northward will have a good chance to see it. Venus and Mars both set as dusk deepens during the first days of August. Venus reappears as a morning star about September 10: from then on, Venus will be continually higher and brighter, reaching almost its greatest possible brilliance and rising two hours before dawn by the end of the month. Jupiter is in the constellation Libra, low over the southwest horizon. It sets about half an hour after the times for using the September roll-around map. It remains very brilliant but continues to fade gradually. Saturn is quite bright. During August, it continues its "retrograde" (westward) apparent motion. On September 4, Saturn seems to turn and resume its normal, eastward course. The planet is easily found above the "teapot" in Sagittarius, which is low over the south on the August map and between south and southwest on September.

NOTE: Natural History for October, which will reach its subscribers in late September, will contain suggestions for viewers of the solar eclipse at dawn on October 2.



Brilliant capella, *above*, is the guide to radiant of the Perseids' display in east. The time is 4:00 a.m., in mid-August. Bright Fomalhaut, *below*, is a similar pointer for Capricornids and Delta Aquarids—to the south at 3:00 a.m.



A CALENDAR OF EVENTS during August and September is arranged here in almanac fashion.

August 5: Little Mercury is in "inferior conjunction" — that is, it has been swinging round to come between the earth and the sun. On this date, Mercury reaches and passes the imaginary line joining the two.

August 10-13: It will be worthwhile to go out before dawn these mornings to watch for displays of Perseids (see chart and comments on the preceding page).

August 11: The first quarter moon and Jupiter make a striking display over the southwest horizon between 9:00 and 10:00 P.M. (see the August map, *below*).

August 13: About 1:00 A.M., the moon and Saturn will be almost side by side over the southwest, with Saturn only slightly higher and a little to the left of the moon.

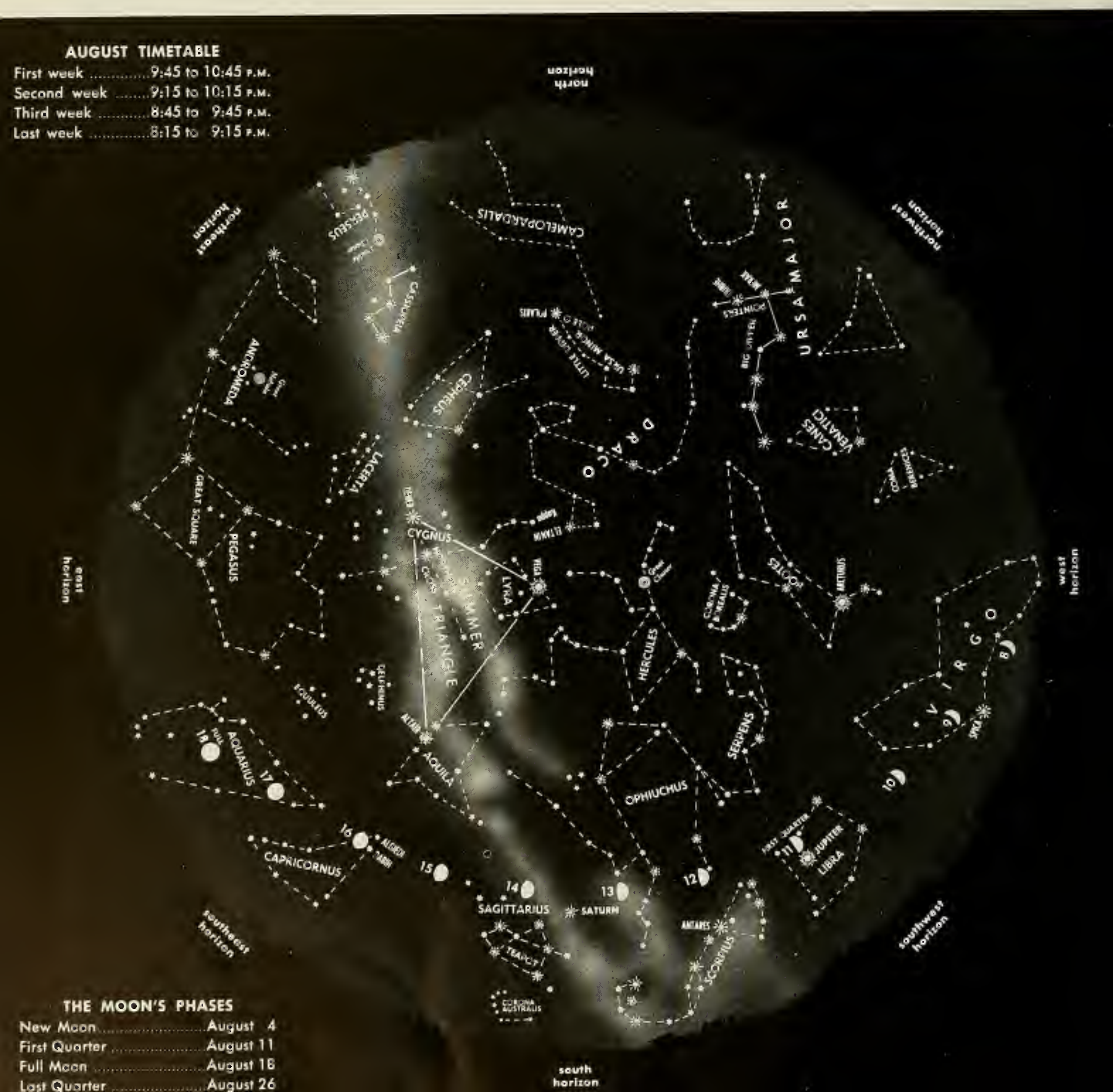
August 15: Venus is at "aphelion" — the point in its orbit most distant from the sun — but the planet is too nearly in line with the sun for us to be able to see it.

August 23: This is the morning for those in northern latitudes to be out before dawn for a look at Mercury in the east (see planetary notes on the preceding page).

September 1: Today, Venus swings in between sun and earth — "inferior conjunction." The planet will now appear farther and farther to the west of the sun. After mid-month, it will be a brilliant morning star in the east.

September 4: The planet Saturn ends its illusion of westward motion: we will now see it move eastward again.

September 10: This is the best night to let the moon introduce you to Saturn. About 9:30 P.M., roll September map around with the bottom between south and southwest. The two will be nearly the same height above the horizon, with Saturn the bright object to the right of the moon.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LITTLE DIPPER
ANDROMEDA
CEPHEUS
DRACO
CANES VENATICI
COMA BERENICES
LACERTA
GREAT SQUARE
PEGASUS
DENEB
CYGNUS
NORTHERN CROSS
SUMMER TRIANGLE
LYRA
VEGA
ELTANIN
HERCULES
CORONA BOREALIS
BOOTES
ARCTURUS
VIRGO
SPICA
SERPENS
OPHIUCHUS
EQUULEUS
DELPHINUS
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FULL
CAPRICORNUS
ALGEDI
DABIH
SAGITTARIUS
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SATURN
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SCORPIUS
FIRST QUARTER
JUPITER
LIBRA
CORONA AUSTRALIS
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AUGUST TIMETABLE

First week	9:45 to 10:45 P.M.
Second week	9:15 to 10:15 P.M.
Third week	8:45 to 9:45 P.M.
Last week	8:15 to 9:15 P.M.

THE MOON'S PHASES

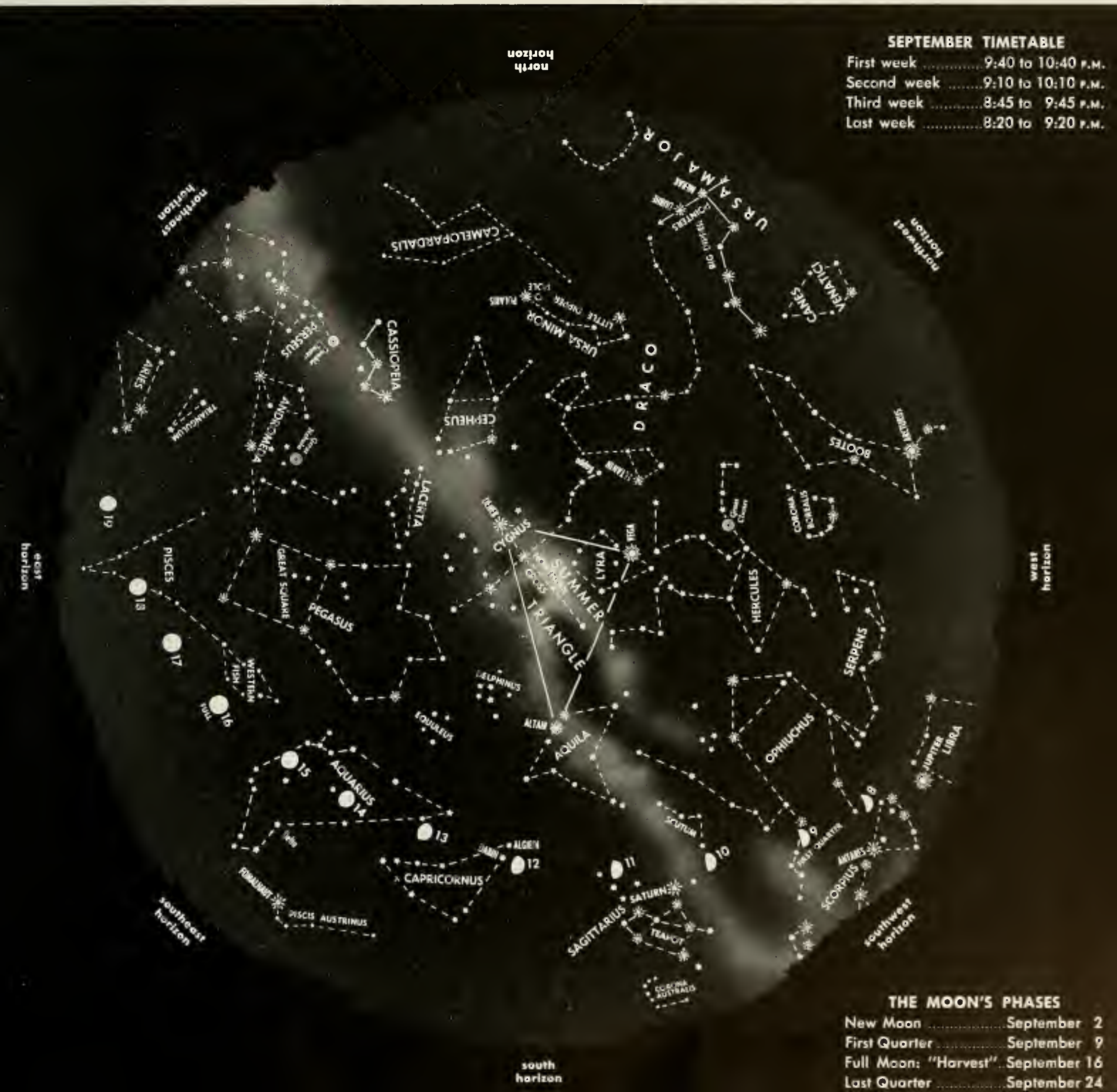
New Moon	August 4
First Quarter	August 11
Full Moon	August 18
Last Quarter	August 26

September 15-19: This is the period of the Harvest Moon. Full moon is on September 16. The moon rises some forty to fifty minutes later each succeeding night, but at Harvest Moon time this interval is much less. For our mid-latitudes, the interval between moonrise on September 15, 16 and 17 will be thirty-three minutes. The interval between September 17 and 18 is only thirty-one minutes: between September 18 and 19, thirty-two minutes. Contrast this with the start and end of the month. On September 2, the moon rises an hour and three minutes later than the night before: on September 30, it rises an hour and four minutes later.

September 22: At about midnight, tonight, watchers in the eastern part of the country may see the moon pass before — and "occult" — the first magnitude star, Aldebaran, in Taurus. The times will be different for different locations. For Washington, D.C., the occultation will begin at fourteen minutes past midnight, EDT, and the star will not emerge until nearly an hour later. The moon, nineteen days old and nearing last quarter, will have a leading edge so brilliant that it will be difficult to see Aldebaran at the moment of occultation. But the following edge of the moon will be dark: this will help dramatize the sudden reappearance of the star when the moon has passed.

September 23: Autumn officially begins at 3:09 P.M., EDT. Since late last June, the sun has been moving farther south each day. At this minute — the Autumnal Equinox — the sun will cross the earth's equator on its way to its far south position (winter in the Northern Hemisphere).

MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this regular feature for NATURAL HISTORY.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CAMELOPARDALIS
PERSEUS
CASSIOPEIA
LITTLE DIPPER
POLE STAR
URSA MINOR
DRACO
CANES VENATICI
ARIES
TRIANGULUM
ANDROMEDA
CEPHEUS
BOOTES
ARCTURUS
CORONA BOREALIS
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SUMMER TRIANGLE
LYRA
VEGA
HERCULES
GREAT SQUARE
PEGASUS
PISCES
WESTERN FISH
SERPENS
DELPHINUS
EQUULEUS
ALTAIR
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SCUTUM
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ANTARES
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ALGEDI
DABIH
CAPRICORNUS
FOMALHAUT
PISCIS AUSTRINUS
SATURN
SAGITTARIUS
TEAPOT
CORONA AUSTRALIS
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SEPTEMBER TIMETABLE

First week	9:40 to 10:40 P.M.
Second week	9:10 to 10:10 P.M.
Third week	8:45 to 9:45 P.M.
Last week	8:20 to 9:20 P.M.

THE MOON'S PHASES

New Moon	September 2
First Quarter	September 9
Full Moon: "Harvest"	September 16
Last Quarter	September 24

ARCTIC

In the North, maturation is

By John J. Koranda

FOR THE PAST FIVE YEARS, it has been my privilege to spend part of my time working in northern —or arctic—Alaska on various biological projects. The main object of my attention has always been some form of the region's plant life. Now the tundra of northern Alaska, except for a few elevated areas, presents one outstanding characteristic to the botanist—the vegetation, in its entirety, is spread out at his feet. The tundra's general appearance is similar to a prairie's—one can observe many interesting details merely by looking down. In fact, the field-worker on the tundra, finds himself kneeling a good deal of the time to look at a lemming burrow, to collect a plant, or to count the eggs in a bird's nest. In this two-dimensional world, all life lies exposed on the ground before an attentive observer's eyes.

The bird life of the tundra is in essentially the same attitude—right at one's feet. This is especially true at nesting time, and such a happy accident of the environment cannot help but delight those whose avocation is "birding." There are no trees and only a few bluffs; the majority of the birds that one encounters will, then, be in the open. There is no need to spend hours gazing into the foliage of trees to catch a glimpse of an elusive warbler, or to climb thirty feet into the branches of an oak to look into a hawk's nest—this type of birding is left behind, with the temperate zone. If one approaches slowly and cautiously on the tundra, many close-up pictures can be taken: I have photographed a male red phalarope and female old squaw duck with a normal fifty millimeter lens, at a distance of little more than three feet.

THE arctic spring comes simultaneously with the strange, twenty-four-hour daylight of the high latitudes. Its swift arrival seems to set the tempo of arctic biology: the nesting cycles of the birds, the growth periods of the plants, and the reproductive activity of the arctic mammals

SUMMER

a breakneck race against time

Eider ducks come north in May, when tundra near Barrow is still under snow.

are all compressed into the three ephemeral months of summer. Yet the temperatures, during this period, are seldom very far above freezing, especially in coastal areas (where most of my observations have been made). The snowy owl, for example, incubates and hatches its eggs from mid-May to mid-July and completes its nesting cycle by the end of August or early September. The young must grow fast to be strong enough to withstand the rigorous weather of late August—for freezing rain and snow may fall as early as August twentieth. Birds that are not fully fledged do not have much of a chance. Thus, a late spring and an early fall may considerably shorten the arctic summer, and it is very possible that some species may completely fail to raise their young during a short season.

Some weeks before the spring thaw, the eider ducks – Pacific, king, Steller, and spectacled—have already passed north and east along the coast, over the open leads in the ocean ice and the snowbound tundra. The snowy owls have mated, and their nests, located in slight depressions on mounds or other high spots that may still be covered with snow, usually hold six or seven eggs—with the clutch size going as high as eleven eggs in record years. It is not uncommon, at this time, to find a snowy owl's nest with a small snowdrift around it, and the edge of the nest showing an icy rim—snow having been melted by the warmth of the incubating female's body and then re-frozen.

The melt-off of the tundra's snow cover occurs with amazing speed, and soon many bare spots are visible. At this time of year, one can almost hear the tundra hum with awakened life processes—although the sound may be only an early bumblebee droning by in quest of the first *Pedicularis*, or lousewort (called the bumblebee plant by the Eskimos).

Some mammalian activity may also be seen at this time. A least weasel may furtively poke its head out of a

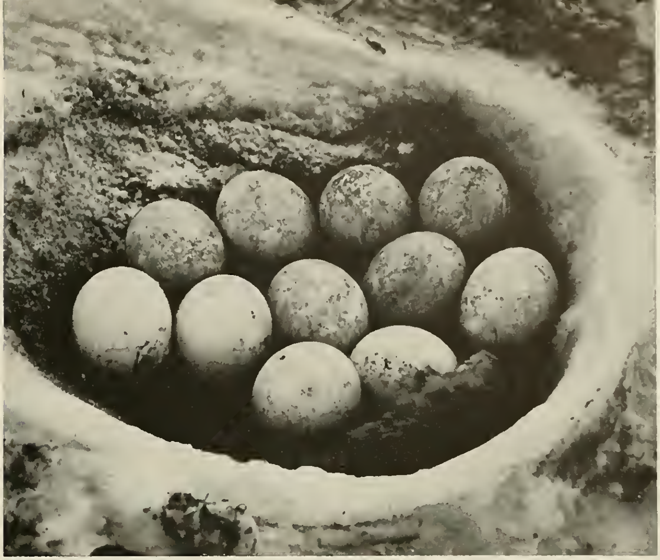
Spring melt-off on tundra near Umiat, abetted by twenty-four-hour daylight of mid-May, comes suddenly. Sedges are in bloom, and many birds have arrived.

Young snowy owl is held by member of arctic study group. By August, when photo was taken, birds must already be big enough to resist frigid weather.

snow tunnel to look about impudently and then dodge back into the snow, only to appear a few feet away for another quick look. These smallest of weasels are, like the snowy owl, predators of the lemming and are small enough to enter the lemming's burrow in their hunt.

Although this article is mainly concerned with the birds of the arctic summer, some remarks on the lemming are appropriate, for this rodent plays so important a role in the life histories of several arctic birds that the birds' story is otherwise incomplete.

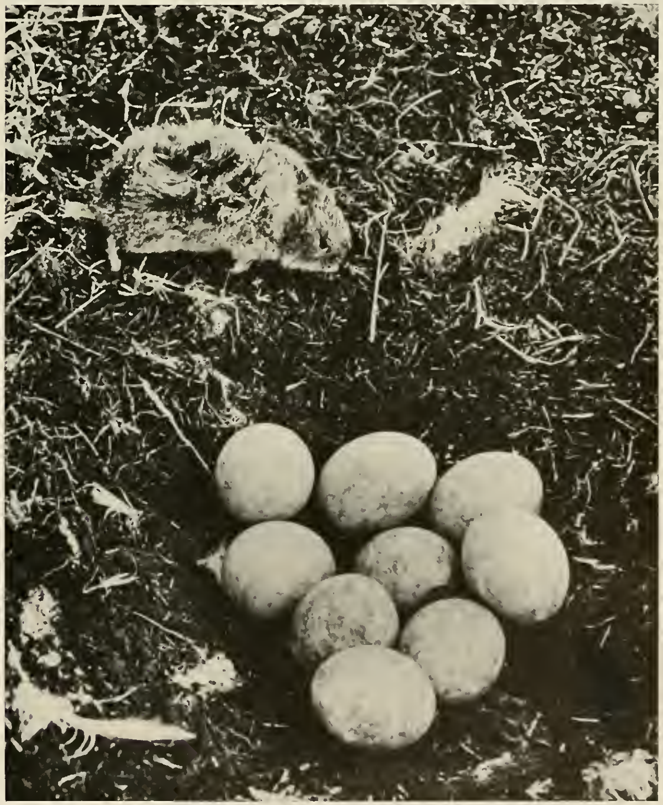
These bobtailed creatures, then. are common to the circumpolar areas of the Northern Hemisphere. Two kinds are present in northern Alaska —the brown and the collared lemming. The collared, or varying lemming, changes the color of its pelage



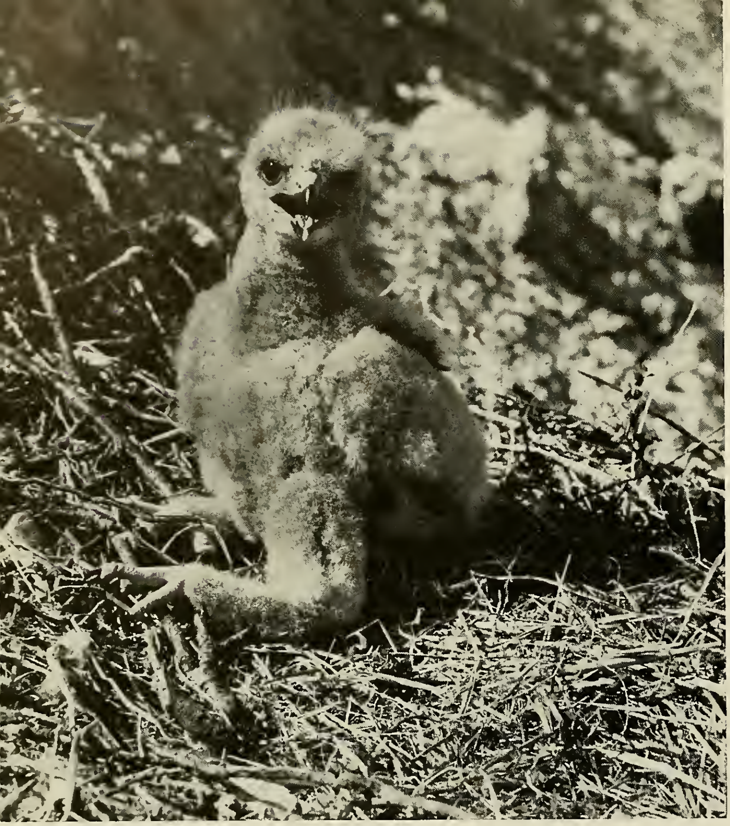
Edged in ice, a snowy owl's nest holds a clutch of eggs during arctic May. Ice was formed when warmth of incubating female melted snow, which froze again.

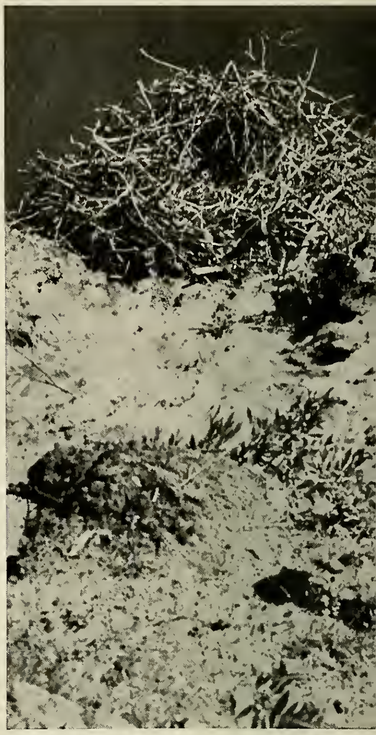
from a variegated brown and black to a winter white. It is found on the higher, often wind-swept ground, and its habitat is not completely snow-covered—as is the brown lemming's—during winter. The brown lemming is the more numerous of the two, and forms the main diet of the snowy owl, the pomarine jaeger, and, very likely, the weasels. In addition, several other animals—such as foxes, both red and arctic, and the short-eared owl, when it is present—prey upon the lemming.

During the melt-off period, the lemmings will scurry from one snow patch to another, in a brown blur of anxiety—for, on the snow-free areas, the sedge grass vegetation is extending green, growing points and the cotton grass may be in flower, while a few feet away, there is still a foot or two of snow. In these open areas the busy lemmings seek and find their first green forage of the summer.



Nest in June, complete with lemming, is finally free of ice. Since lemmings form owls' main diet, nesting activity parallels size of lemming populations.





Rough-legged hawk nestling is shown at left. *Above,* a scientist inspects nest

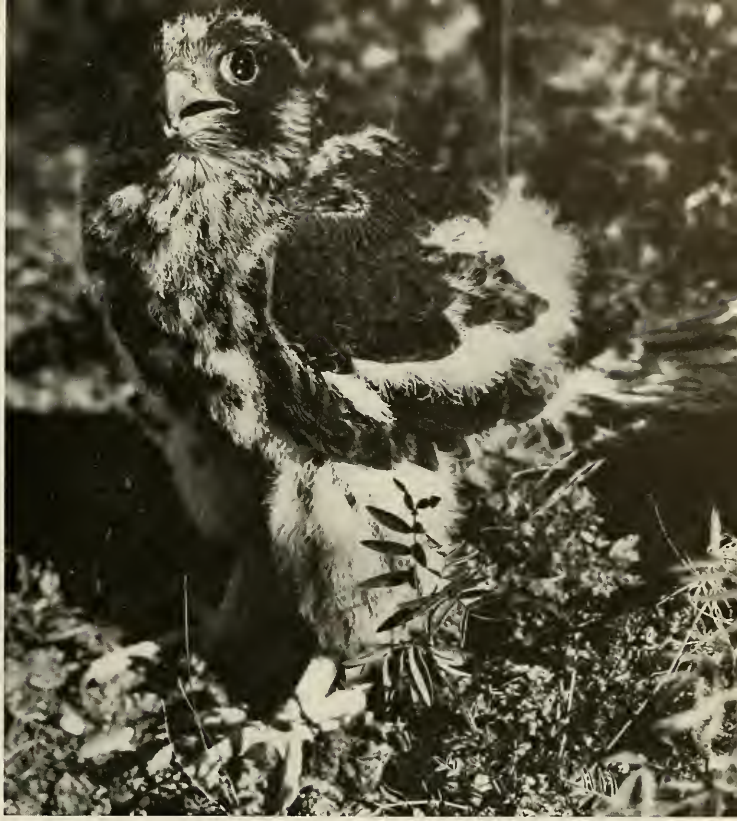
A lemming's evidences of anxiety, while on the patches of open tundra, are justified—there is a good possibility of its being scooped up in the efficient bill of a hunting jaeger. The pomarine jaegers may arrive on the tundra near Point Barrow in late May or early June and begin foraging successfully over the tundra while the snow cover is still complete. Tiny tracks on the snow leading to the disemboweled body of a lemming, surrounded by wing marks and the impressions of webbed feet, give mute testimony to the drama that has taken place. Glaucous gulls may also join their jaeger brethren in the hunt for lemmings early in the spring.

The interrelationships of these arctic animals—especially the snowy owls, lemmings, and jaegers—as studied by Frank A. Pitelka and his associates, is one of the most fascinating ecological histories that has been written. The lemming populations in arctic areas have long been considered classical examples of fluctuating, or cyclic, animal populations. Such is the intimate relationship of prey and predator that the phases of a lemming cycle cause corresponding effects in the populations of animals that prey upon them.

This principle is seen very graphically in the nesting of snowy owls in the Point Barrow area. During years when the lemming population is low, nesting pairs of snowy owls may be wholly absent; or one may find only from two to five pairs present, and these may not nest. But when the lemmings are abundant, as many as twenty nesting pairs of owls can be found in the same area. The number in the clutch of eggs laid by snowy owls also apparently increases during the lemming populations' "highs."

An interesting feature of the story is that the snowy owls become abundant and begin their nesting long *before* the tundra is free of snow and the lemmings become more accessible.

site, perched precariously on the cliff's edge. At right is a growing peregrine.



Pomarine jaeger was photographed as it harassed biologists venturing into its nesting territory. Snowy owls and even golden eagles give way before it.

Long-tailed jaeger at the left, like its pomarine cousin, is quick to attack all intruders violating its territory—such as this scientist, photographing its nest.

The jaeger populations, especially those of the pomarine, apparently exhibit a similar relationship.

The snow bunting and the Alaskan longspur are also present on the tundra at the outset of summer. The snow bunting may arrive on the Arctic Coast as early as April, and its presence is taken by the Eskimos as a sure sign of the end of winter. The snow buntings sing relentlessly "all night," and so do many of the arctic birds. I say this from experience, for field observations are often carried on late into the twenty-four-hour day, and scientists working in the Arctic may find themselves living on an inverted schedule—that is, sleeping half the day and working late into the night. All through the night, the phalaropes wheel and dip on the ponds, the pectoral sandpipers make their curious territorial flights, and the hunt for seeds, insects, and food goes on. One might say these arctic animals seem to realize that their task of reproduction must be accomplished in this incredibly short time, and so utilize all the hours of the twenty-four.

The passerine species are not abundant in this region, although an eastern robin was once found several miles out on the ocean ice, and there are occasional records of Asiatic species in this area. The snow bunting will utilize any crevice or cavity for its nest-building and readily make use of artifacts for nest sites. Once, while eating lunch on the long gravel spit that extends into the Arctic Ocean from Point Barrow, I saw a female snow bunting dodge quietly into an abandoned cooking pot. Looking inside, I found a nest and four hungry nestlings. Old Eskimo sod houses are also used by the snow buntings, and they will even use lemming burrows for nest sites.

About the time that pools of meltwater form on the tundra, a small shorebird—the red phalarope—may be seen bobbing and dipping on them. The red phalarope arrives along with several sandpipers—the least, pectoral, red-backed, and Baird's, and perhaps the ruddy turnstones. Soon the tundra

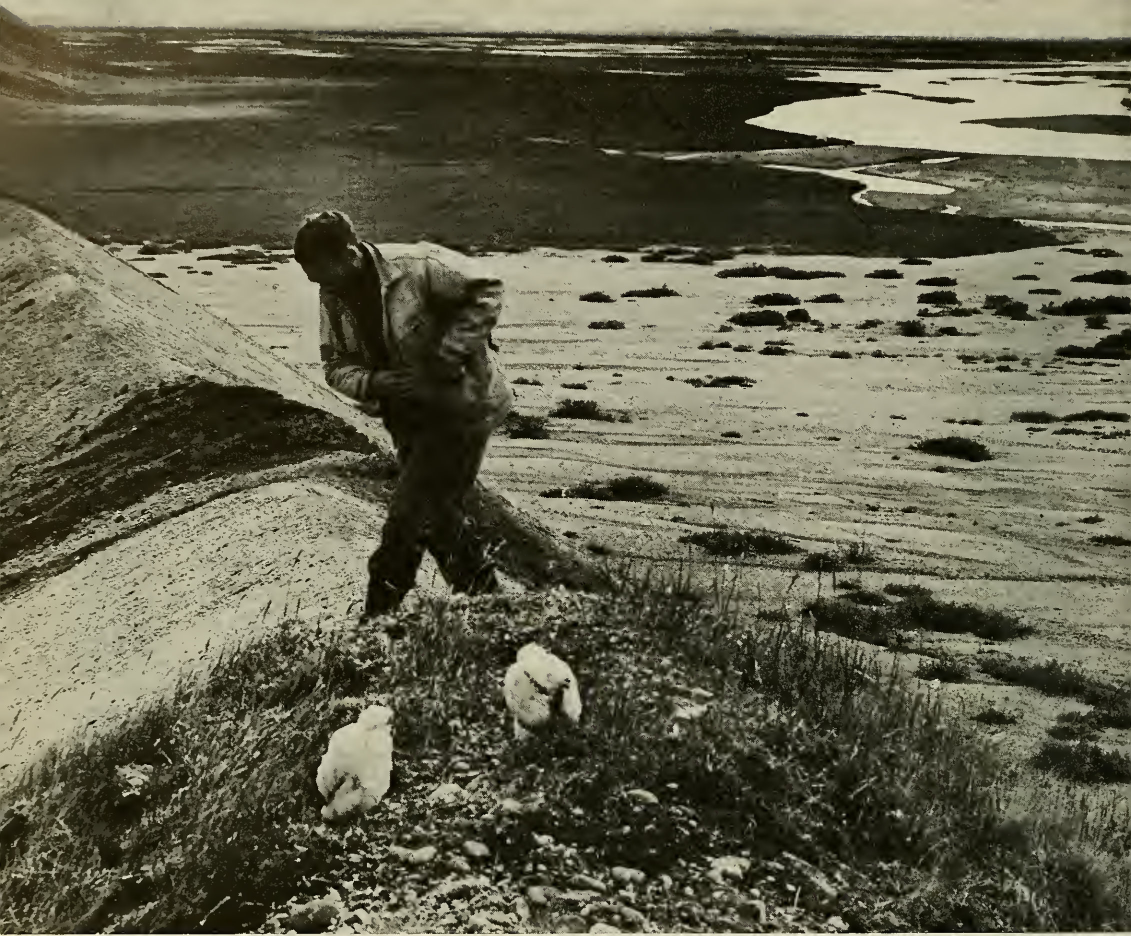
Aerial view looking south shows face of Franklin Bluffs and Sagavanirktok River. Arctic Research Laboratory team studied this region in summer of 1958.

is alive with avian activity. The jaegers—pomarine, parasitic, and perhaps the long-tailed—have begun to establish nesting territories and are very insistent upon respect for these areas from both man and animal. The pugnacious pomarine jaegers have even been seen to dive at vehicles.

A pair of jaegers will defend a well-defined plot of tundra, in the center of which is located their nest. When a person walks across the tundra and passes from one jaeger territory to another, successive harassment by first one pair of jaegers and then another will occur as he comes within critical distance of their nests. Other jaegers, snowy owls, and even the golden eagle will retreat before the attacks of a defending jaeger. And, I might say, quite a few humans also retreat, for these birds have the unnerving habit of flying directly at one's head, checking their swoop only at the last moment. Several times their feet or wings have struck my head.

The snowy owls now have fluffy, white nestlings and may ring their nests with as many as eighty slain lemmings, apparently assuring that young and brooding mate are well-fed. From information obtained by keeping young owls in captivity, it seems that four to six lemmings per day are required for each young owl in the nest. Sometimes the lemming is swallowed whole—which is quite a task, for some lemmings weigh well over a hundred grams. The snowy owls will seldom defend their nest when humans approach; usually, the birds retreat silently to a nearby hummock. But whenever an animal approaches, the owl will protect its nest very vigorously. I have seen Eskimo dogs harassed so effectively that they soon left the area.

Eider ducks and other ducks also nest in the Barrow area. The pintail and the old squaw ducks commonly nest on the tundra. The arctic tern



Peregrine falcons and nest are inspected in early August by biologist looking for pellets, which give clues to bird's diet. Falcon aeries are found inland, on the bluffs that line some of major rivers. The scene above is at Franklin Bluffs.

will also nest in the Barrow area, on the shores of inland lakes and ponds. Loons — Pacific and red-throated — may be seen flying toward the ocean for their feeding. Some of the inland lakes in the Barrow area have sticklebacks in them (and one is known to contain whitefish), but the loons probably have to visit the ocean for a sure catch. The nasal cry of the loon has an almost ventriloquistic quality on a still, cold night on the tundra; one may turn several times, vainly trying to locate the calling bird in the sky.

This, then, is the tundra scene along the Arctic Ocean in June and July. Other species of birds are present, of course, but the ones I have mentioned will surely be seen. The young birds and animals seem to grow with incredible speed. It seems that the snow has been gone only a week or so when the precocial young of some shorebird can be found skittering through the sedge and grass. The young lemmings produced during the summer make their appearance in mid-July: the rodents are sexually mature before growth is complete. By August, in consequence, the lemming population is composed mainly of young that are the litters of late-winter young that are now adults themselves. The young owls remain in the nests into August, changing gradually from downy, awkward, sprawling nestlings into large, yellow-eyed, dignified-looking birds, with white feathers appearing in their dark gray, juvenile plumage.

Farther inland, where bluffs occur along some of the major rivers. the falcons and their aeries will be found. The shrill cry of the rough-legged hawk is heard long before one reaches the nest. Gyrfalcons and peregrine falcons are also energetic in defense of their nests and give many an anxious moment to those who observe or photograph their nestlings.

Long-billed dowitchers are seen inland along the rivers. while the yellow wagtail is found in some of the sheltered ravines that support a shrubby willow growth. And the male willow ptarmigan will attempt to lure an intruder from its nest and chicks in the best broken-wing fashion. The incubating female ptarmigans, by contrast, will hold to the nest, permitting very close inspection. The female ptarmigan is well camouflaged at this time of the year, and one may look directly at a female on the nest for several minutes before detecting the bird in the vegetation.

One interesting example of this defense of the young was observed by several of us in 1957. The jaeger's usual diet is the brown lemming, but occasionally it will take small birds. A pair of ptarmigan, raising a brood of chicks on the tundra—rather than in the willows, which would have offered some protection — were approached by two long-tailed jaegers that began to dive repeatedly on the chicks. At each dive, the adults rose and met the swoop of the jaeger before the attacker could strike the young. At last, the predators departed.

The jaegers are not always so easily dissuaded, however. On the Sagavanirkok River, I watched a pair of parasitic jaegers chase a small shorebird, about the size of a Baird's sandpiper, for at least five minutes without stopping. The sandpiper used the most erratic flight possible, but the jaegers—working as a team and duplicating every movement of the sandpiper—finally caught the bird.

At Point Barrow, the summer that would climax the nesting season may sometimes fail to come. By the middle of July, the young snowy owls are ten inches high and have lost some of their juvenile down. If the food supply—the brown lemming—is abundant, perhaps a third or a half of the clutch will be developed enough to fly before the arrival of cold weather in late August and September. The young owls grow fast, and there are white feathers in their plumage by the middle of August. Soon they are as big as the adults and ready to set off on their own.

The jaegers have zealously guarded their nesting territories and their "ugly duckling" young can be found by late July, flapping about on the tundra and flying for short distances. The parent birds attend them for a while during this period. One young jaeger, under study in our lab, would wander up and down the hallway, scolding and looking for something—anything—to eat. It would even peck at the lolling tongue of our pet dog. Soon the young jaegers are on the wing, gathering in small flocks along the coast with the mature birds, ready to assume their part-raptorial, part-gull-like, adult role.

With luck, an observer may come across the downy, daintily marked young of the golden plover. Being precocial, these young birds leave the nest soon after hatching and skitter about on the tundra — their coloring as their only defense. The adult golden plover is one of the handsomest birds to be seen in the Arctic. It is an upland bird: its plaintive cry is a familiar sound throughout the inland tundra.

The red phalarope, which occurs at Barrow in large numbers, is commonly seen wheeling and dipping in the tundra pools. The phalarope paddles with one foot and stabs into the water with its bill at the same time; the objective of this "whirling dervish" attack is the myriad crustacea to be found in the tundra pools. The male phalarope incubates the eggs, developing four brood patches on his breast. By now, the snow buntings and longspurs have all succeeded in raising their broods. The local eider ducks with their young are to be seen on the tundra lakes near the coast.

Of all the tundra's bird life, the Pacific loon is difficult to surpass for sheer delicacy of coloring and gracefulness of form. One of these striking birds, serenely sitting on its nest by a small lake, is a sight not soon to be forgotten. The young are a uniform gray, and will often flatten themselves out on the water or attempt to hide in the grass when one approaches.

By late August, the weather at Bar-

Peregrine nestling was photographed early in June at the Ikpikpuk River. Like the jaegers, the peregrine falcon adults defend their nestlings fiercely.

Pacific loon was photographed on nest near a small lake. Although some inland lakes have an abundance of sticklebacks, loons must go to ocean for sure catch.

Red phalarope swims in a small pool near Barrow. Phalaropes have habit of whirling about, paddling with one foot while jabbing water with bill for prey.

A botanist who summers in Alaska, Mr. Koranda has been aided in his Arctic Research Laboratory work by a contract between the ONR and the Arctic Institute of North America.

row may turn bitterly cold: snow and sleet are known as early as the middle of the month. Often, the young of such birds as the phalarope are not strong enough to leave with the adults when they move south: they die during the first cold spell. The snowbirds now gather in flocks along the coast and gradually drift southward. The eider ducks have been flying south in large numbers since the middle of the month or earlier, usually following the coastline very closely.

These are the signs of the coming arctic winter: a change in the color of the tundra—especially in the aquatic grass, which becomes a brilliant red—and the passage of the eider ducks down the coast to the southwest. The gradual disappearance of the summer resident birds is another sign, for few birds winter in northern Alaska, although the golden eagle, the gyrfalcon, the ptarmigans, and the snowy owl are residents that seem to be able to survive in the austere environment of an arctic winter. Some of the summer birds migrate as far south as the southern United States and even to South America (the golden plover and arctic tern). Late in the fall, one may see an immature and inquisitive arctic fox loping across the tundra. Later still, the collared lemming and the least weasel will molt into their white, winter pelage.

As the lakes freeze over, a thin mantle of snow covers the sedge tussocks, and the observer sees little activity on the tundra. Perpetuation of the life of this region, the tundra's plants and animals, has been accomplished within a very brief span—from about ten weeks to three months.

During the first week of August, the sun dips below the horizon for the first time since May, reminding one that the sun usually sets although it has not done so all summer in the Arctic. Gold and purple sunsets color the subfreezing water of the Arctic Ocean. By the end of September or early October, when the eastern United States experiences the brilliant coloring of autumn trees, winter has taken hold of the tundra for another long nine months.

Hungry redpoll nestlings open mouths wide for food in home in willow tree. Such shrubs, rare on the arctic tundra, are found only in hollows. Small finches, the redpolls take their name from the red crown that adult males often have.

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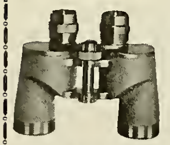

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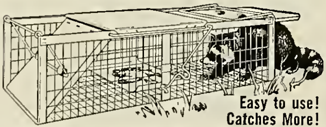

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REVIEWS *(cont'd from page 368)*

reduced to one-half, one-fourth, or one-eighth, to create an eerie conglomeration. The reaction of listeners is fairly uniform. Each is tempted to coin the same phrase: "It's not just *of* the birds—it's for." Nevertheless, it is an ingenious enough bit of work.

Less earnest tape splicers have also joined the act. One record—of alleged dogs, ostensibly trained to bark on command and produce such simple tunes as "Jingle Bells" (*Don Charles Presents the Singing Dogs*, VICTOR, 47-6344)—is likely to produce a uniform listeners' comment: "It shouldn't happen to a."

A FASCINATING and informative analysis of bird songs is contained in a set of four twelve-inch, 78 rpm records distributed in California by the Cooper Ornithological Society under the title *Music in Nature*. This is a lecture by Loye Miller, whose highly skillful imitations of birds and other animals, rather than field recordings, illustrate his instructive discussion.

Were it possible to combine Dr. Miller's charm and talents as a teacher with the nimble tape work of Fassett, a truly outstanding record could be produced. The narration accompanying many field recordings does little to enhance the understanding of anyone anxious to know the motivation, or the adaptive significance of voice as a conspicuous attribute of birds. For inexplicable reasons, many ornithological narrators feel impelled to imitate, rather than evaluate, the sounds they introduce. Frequently, they waste space on the record that could more profitably be devoted to explaining how animals make use of sounds. Indeed, whether he seeks to add a poetic touch or explain the biological importance of the sounds, there is little point in any narrator's cluttering his record with detailed information concerning the time and place where each sound was recorded. Documentation of this sort should be included, instead, in leaflets with each album.

This more sensible procedure is followed in *Witherby's Sound-Guide to British Birds* (H. F. AND G. WITHERBY, LTD.). A bound booklet accompanying each set of recordings tells not only where individual species were recorded, but also

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This list details the photographer, artist, or other source of illustrations, by page.

361—Gábor Éder; Lee Boltin.
362—AMNH.
364—AMNH.
366—AMNH.
370-79—Arline Strong.
380-81—Howard E. Evans.
382-83—AMNH drawings, top; Howard E. Evans.
384-399—Matthew Kalmenoff.
401—Helmut Wimmer, AMNH.
402-3—Sky maps by Henry M. Neely.
404-15—John J. Koranda.
420-21—Vera Newton, left; Anne Ophelia Todd.
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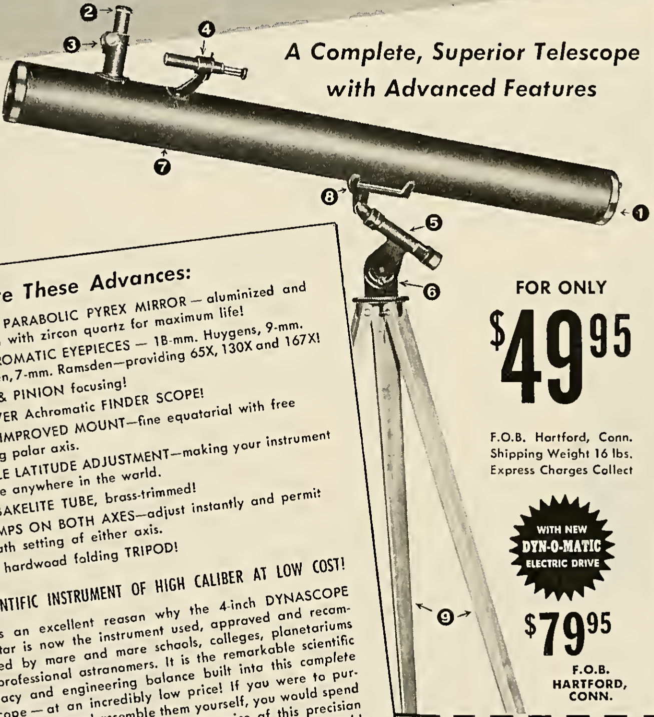

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the nature of the sounds, whether they represent flight calls, alarm calls, or any of several others. On the records, themselves, only the vernacular name of each species identifies its call, and there is no additional narration beyond an introductory message. The *Sound-Guide* manages to supply information for an impressive total of one hundred and ninety-five species. This required careful editing, with each species represented by no more sound than is needed for comparison, recognition, or appreciation. However, bird-watching is a serious business with the British, who offer no encouragement to dilettantes. The booklet contains the suggestion that the records be taken into the field and played on a portable gramophone: the *Sound-Guide* is avowedly for "identification rather than enjoyment."

The Yankee producer of a purely utilitarian record called *Echoes of the Pied Pipers of Hamlin* (Pied Piper Sales) is equally frank. In his introduction, he makes it plain that "this is not a pretty record," but one designed to get rid of rats. A leaflet, accompanying the record, explains that "...rats are wise, but they are the spookiest rodent on earth. Once frightened by something they don't understand, they leave in one bunch with a leader, and they won't come back." What rats "don't understand" in this case is the screeching of a frightened rat, and the record becomes a "rat eradicator" if these sounds are reproduced where all rats in any building will hear it. At least, that is what the producer says.

Such uses of sound recordings deserve more investigation. Broadcasts of starling distress signals met with temporary success in discouraging these birds from roosting on buildings. Attempts have been made to use sound in devising ways to exterminate mosquitoes, but no records have been issued for such purposes. There is, of course, no reason for restricting records to sound with esthetic appeal. Yet, it is also possible to combine the useful with the esthetic. Nor need the British feel conscience stricken if enjoyment is gained from records made primarily for the identification of bird calls.

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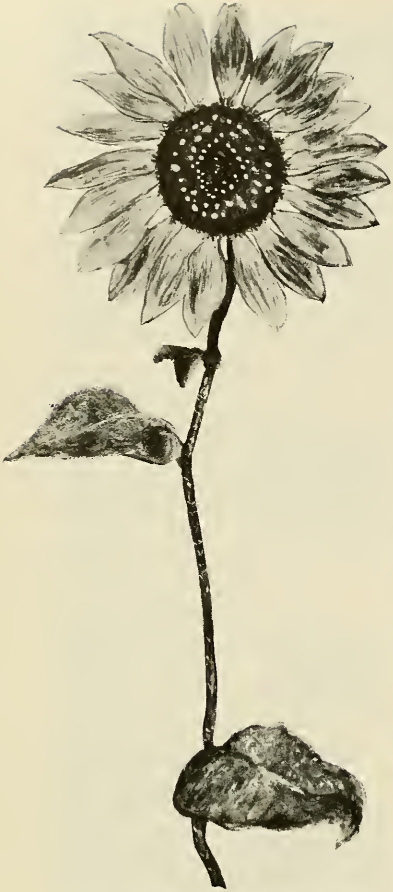
THE RED PRAIRIE SUNFLOWER

A classic experiment with a plant mutation

By Jack McCormick



Wild mutant red sunflower was found in a lot in Boulder, Colorado, in 1910.

IN THE SUMMER OF 1910, in a vacant lot at Tenth Street and Aurora, in Boulder, Colorado, a single prairie sunflower plant with red "petals" appeared among a stand of a hundred or more wild sunflower plants with normal, orange "petals." By happy chance, the vacant lot was on a route occasionally traveled by Mrs. Wilmatte Cockerell, wife of Dr. T.D.A. Cockerell. then Professor of Zoology in the University of Colorado at Boulder. Mrs. Cockerell, an alert amateur naturalist, noticed the peculiar coloration of the sunflower and told her husband of her discovery. Together, they carefully dug up the plant, which Dr. Cockerell recognized as a mutant. They transferred it to their own garden, and there the sunflower continued to bloom.

A few days later, Dr. Cockerell revisited the vacant lot with the hope of finding other mutant plants. Instead, he found that a tidy city official had scythed away the stand of wild sunflowers, which he termed "unsightly weeds." The prairie sunflower is an annual; that is, it blooms but a single year. Since the wild stand had been mowed before its seeds had ripened, it was thus eliminated forever. But for the accident of Mrs. Cockerell's visit, the mutant, red sunflower would have perished, too.

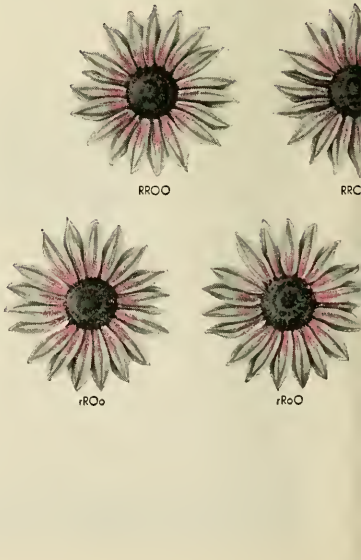
The prairie sunflower is common to Boulder. Its relatively small "blooms" are actually bouquets—composed of a fringe of normally orange-colored, petal-like "ray flowers," which surround smaller, tightly clustered, dark-colored "disc flowers." The colors of the sunflower, like those of other plants, are produced by several pigments. Its leaves and stem are colored green by chlorophylls, the compounds that enable plants to manufacture food. Its orange and yellow colors are produced by pigments of the carotinoid group, also seen in the carrot root and in the autumnal yellows of many leaves.

Both the chlorophylls and the carotinoids are contained in minute, usually disc-shaped bodies, known as plastids. The darker colors of its disc flowers, of the bracts mixed with the flowers, and the speckles on the stem of the plant are produced by anthocyanin pigments. These anthocyanins, which range from scarlet to blue in various species and under various conditions, are dissolved in the sap of the cells.

In the red sunflower, a mutant reported once before—in South Dakota in 1892—but never before cultivated, the dark anthocyanin pigments had increased in quantity, invaded the rays and, in mixture with the carotinoid plastids already present, had produced a chestnut-red color.

Although we still know relatively little about the causes of mutations, these heritable changes occur rather frequently among both wild and cultivated plants. Such mutations may result in greater production, of obvious value in the grain crops. Or they may offer greater cold hardiness, resistance to diseases or insects, or ability to withstand drought. Among ornamental plants, there may be a change in fragrance or, more frequently, changes in color of the leaves or of the flowers. But to be of value, mutants must be found and nurtured.

After the red sunflower was established in their backyard garden, the Cockerells attempted to perpetuate their short-lived find. Their first problem was that a single sunflower is not fertile with its own pollen. In order



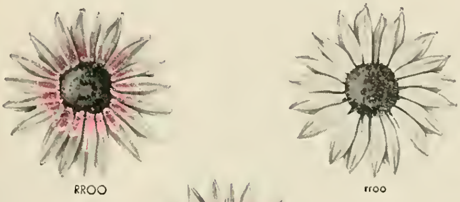
to obtain seeds, it was necessary to breed (or "cross") the single, red sunflower with a normal-colored plant.

When the next summer's blossoms opened, about half of the plants were red-rayed and half were orange-rayed. The nearly even balance in numbers between the two colors indicated that the red color was produced by the presence, in the mutant, of a dominant red gene and a recessive orange gene.

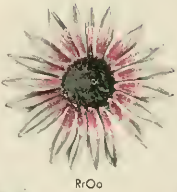
In human families, a similar situation often occurs when a brown-eyed parent and a blue-eyed parent produce a brown-eyed child. Although each parent (and this is true in all plants and animals) generally has two genes for a given characteristic, only one gene of the pair is passed by each parent to the offspring. Blue is a recessive color for eyes, while brown is a dominant color: hence, a blue-eyed parent is "pure blue" and has to pass a recessive, blue-color gene to his or her offspring. The brown-eyed parent, however, passes a dominant (brown-color) gene to the offspring, and the child shows this dominant eye-color. If such a child, who is "mixed" or heterozygous for eye color, marries a blue-eyed mate, approximately half of the next generation will be brown-eyed and half blue-eyed, because the heterozygous, brown-eyed parent will provide a dominant, brown-color gene about as often as a non-brown, or blue-color. The laws of chance operate under such conditions in much the same way as when a coin is flipped—"heads" will show about as often as "tails." The wild red sunflower's dominant genes, crossbred to the normal orange, were governed by these same laws.

The next objective of the Cockerells was to interbreed the red offspring of the first season, in an attempt to obtain plants that were pure, or homozygous, for red coloration. According to the laws of heredity established almost half a century earlier by Gregor Mendel, the Cockerells expected to obtain twenty-five per cent pure-bred, homozygous red sunflowers: fifty per cent would be heterozygous red and the remaining twenty-five per cent would be homozygous orange. This cross can be illustrated by a formula in which "R" is the dominant red gene and "r" is the recessive non-red or orange gene. By crossing Rr with Rr, the possible combinations are: RR, Rr, rR, and rr.

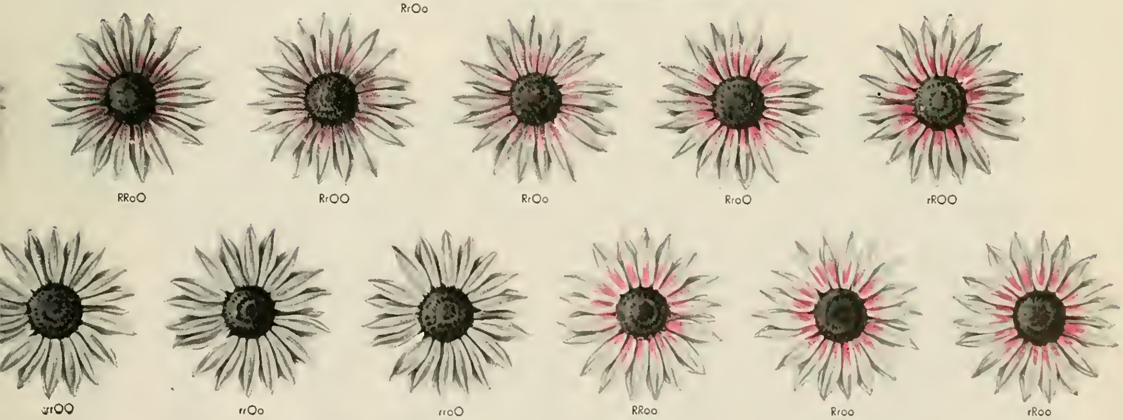
In this experiment, the flowers had to be protected against accidental fertilization by pollen from orange-rayed sunflowers. This was done by covering each flower head with a paper bag before the fertile disc flowers opened. The flowers then were dusted by hand with pollen from other red-rayed sunflowers.

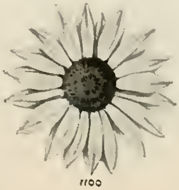


First cross-pollination was made in 1912 between the chestnut-red and a pale yellow, or primrose, sunflower.

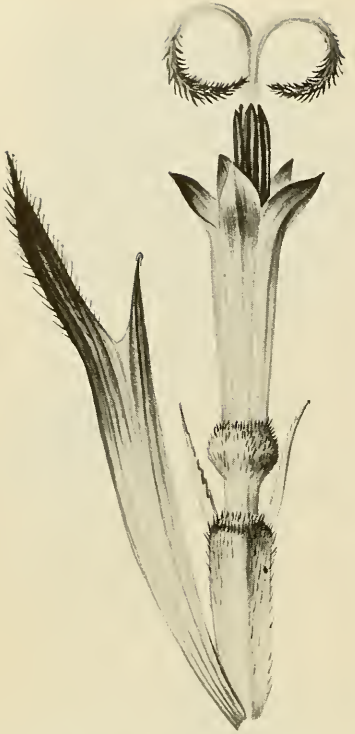


Offspring of this cross were all chestnut-red, *left*, indicating that the red gene was dominant, yellow recessive.





Next generation, *above*, verified that the mutant bred true in 9:3:3:1 ratio of Mendel's law.
The sixteen gene combinations produced four colors.



Disc floret, *above,* shows purple in bract that "escaped" into ray florets.

After they had obtained pure-bred red sunflowers, the Cockerells searched for a way to produce some new and striking floral combination. They had found that the anthocyanin pigment in their red sunflower was really a wine-red color, but it was combined in the rays with an orange background and thus appeared chestnut-red. They learned of a pale yellow, or "primrose"-rayed, mutant sunflower. They reasoned that if their wine-red pigment could be placed on the pale yellow rays, a new effect would result. They grew both types and cross-pollinated them. The offspring were ordinary looking, heterozygous chestnut-red sunflowers.

Now, in the Cockerells' previous crosses, all of the plants had been pure-bred for the orange background colors. However, the primrose sunflowers possessed neither red nor orange. Since the offspring were all chestnut-red sunflowers, the primrose characteristics must have been recessive. This can be expressed in a formula that utilizes R for red, r for absence of red, O for orange background, and o for absence of orange, or the presence of primrose: Parents: RROO (red) x rroo (primrose) = RrOo (heterozygous chestnut-red offspring).

The offspring of this crossing were known to differ from all previous red sunflowers in that they were heterozygous for the background orange color. When these offspring were interbred, there were two pairs of genes to be considered and the possible combination of genes were more numerous. There are sixteen possible combinations, although these sixteen will produce only four colors: chestnut-red (RROO, RrOO, RROo, RrOo), orange (rrOO, rrOo), wine-red (RRoo, Rroo) and primrose (rroo).

Of the 123 plants produced by this crossing, seventy-one were chestnut, nineteen were orange, twenty-five were wine-red, and eight were primrose-rayed. According to Mendelian laws, the theoretical expected ratio would be 9:3:3:1, or—for this number—sixty-nine chestnut, twenty-three orange, twenty-three wine-red, and eight primrose-rayed plants. Thus, the experiment verified the Cockerells' hypothesis that the mechanisms of inheritance of flower color in the sunflower follow Mendel's law.

In addition to variations in color of the rays, the Cockerells were surprised to find that there were also variations in color patterns: the rays were sometimes entirely red; sometimes their tips were yellow or orange. In others, the red was confined to the middle of the ray, and presented an effect of a red ring enclosed by inner and outer rings of orange. These patterns were found to be inherited independently of the color, but became evident only when the dark pigments were present.

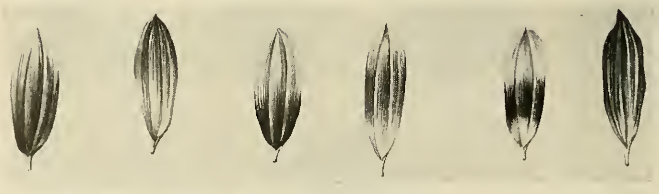
Many variations in form also appeared during the Cockerells' experiments. For example, the ends of the rays were twisted tortuously in some plants. In others, normal disc flowers did not develop, but were replaced by ray flowers (such flower heads are termed "double-flowered"). Some heads had two or three rows of ray flowers: others had the rays deeply cleft at their ends. Another variation was the "collarette," in which a narrow, curled lobe was developed from the base of each ray flower.

Dr. McCormick, who is in charge of vegetation studies at **The American Museum,** often contributes articles on the Plant Kingdom to these pages.

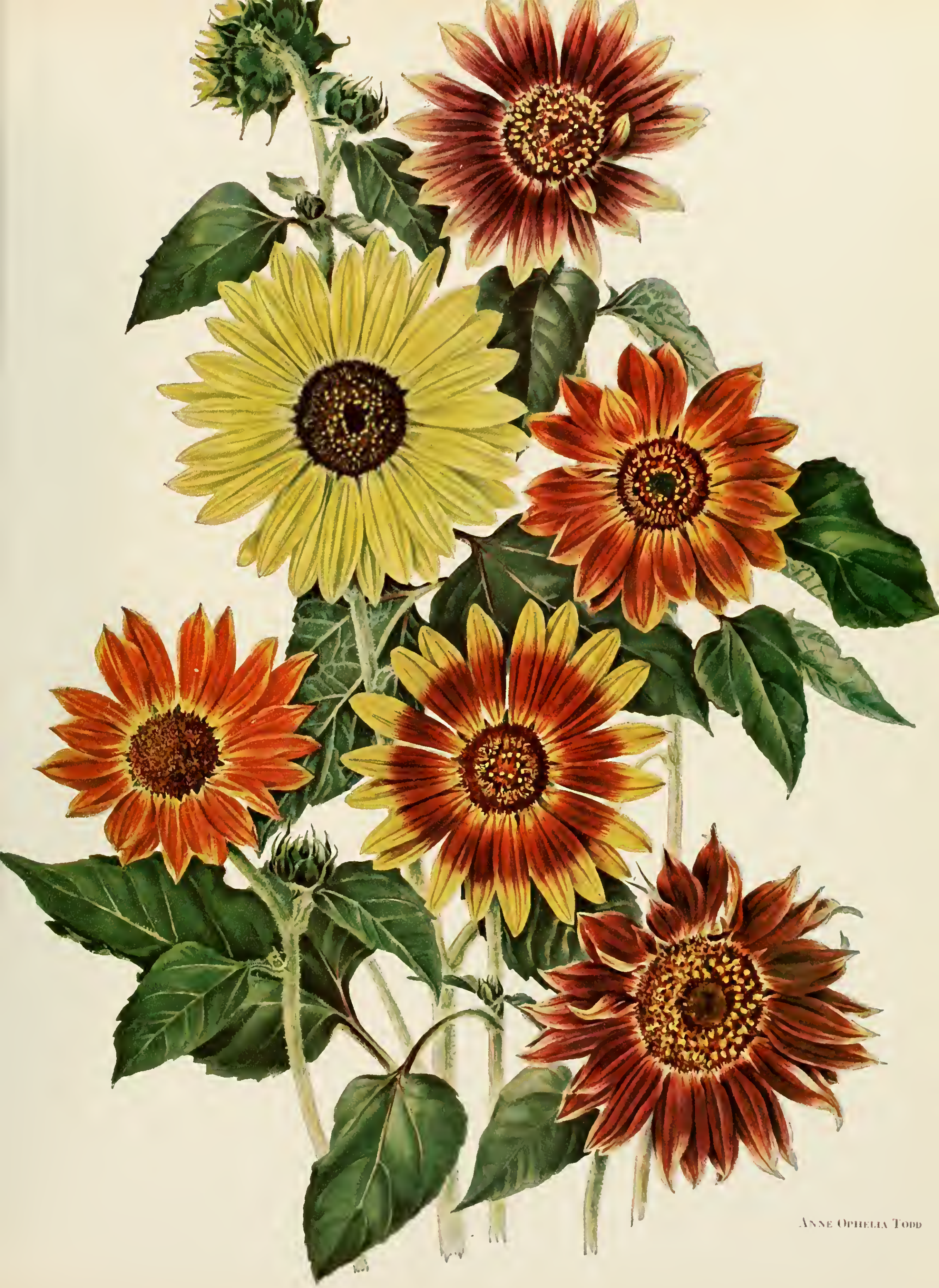
These many variations created a widespread horticultural interest in the sunflowers developed from Mrs. Cockerell's original discovery. An English firm, Sutton and Sons, marketed seeds to all parts of the world. But the plant had a significant weakness that hampered its horticultural success. An annual, it lives only a single season. No roots, bulbs, tubers, or cuttings can be used to propagate choice varieties and preserve their characteristics. Since it is propagated only by seed, any variety of the sunflower can be kept constant only if it is homozygous, or "purebred." It is economically impossible to maintain the great number of pure strains that might represent all the possible sunflower varieties. In addition, the anthocyanin-induced, red colors tend to fade in hot weather and may be affected by soil conditions.

The Cockerells' adventure in plant breeding is but a sample of the fascinating possibilities open to anyone with a few square yards of garden ground and a desire to follow the pathways of experimentation.

The picture of the first red sunflower (*p. 420*) was drawn by one of Dr. Cockerell's students in 1910. The other illustrations are the work of the noted botanical artist Anne Ophelia Todd. Opposite are some of the varieties derived from the Cockerell's painstaking excursion into applied genetics.



Ever-present patterns, never visible in ordinary sunflowers, appeared when red settled in the rays. Some of these varieties are shown in color at right.



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October 1959

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On page 434 begins a description of experiments conducted by Dr. Max Renner and his associates at the Zoologisches Institut in Munich, Germany, on "time sense" in bees. Among the tools the scientists used in their study were the bees, a hive, a feeding station, a series of pigments, and a brush. Some of this curious equipment is symbolized in the cover picture, especially photographed by Lee Boltin.

At the right is a flower-decorated box with a practical purpose. The center of the flower is a hole; beneath it was placed a dish of sugar water from which the bees fed. The pigments shown below were mixed with shellac, and tiny dots of color were painted on the backs of the bees with a fine brush. This color-dot code enabled Dr. Renner and his observers to identify individual bees as they came to feed.

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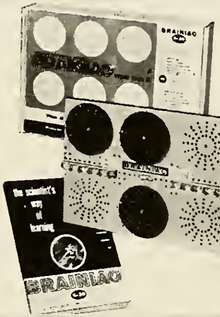

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Reviews

A STUDY OF *LATIMERIA CHALUMNAE*

Reviewed by Bobb Schaeffer

Dr. Schaeffer is The American Museum's Curator of Fossil Fishes.

In 1822, Gideon Mantell, a physician and amateur paleontologist who is famed as the discoverer of the first English dinosaur, published a sizable volume on the geology and fossils of the South Downs in Sussex. The fossils, including a variety of invertebrates and fishes, were mostly collected by Mantell himself in the chalk cliffs—of Cretaceous age—along the Channel. They were illustrated in quaint wash drawings, prepared by Mrs. Mantell. One of the fishes described and figured in this work he named *Amia lewesiensis*.

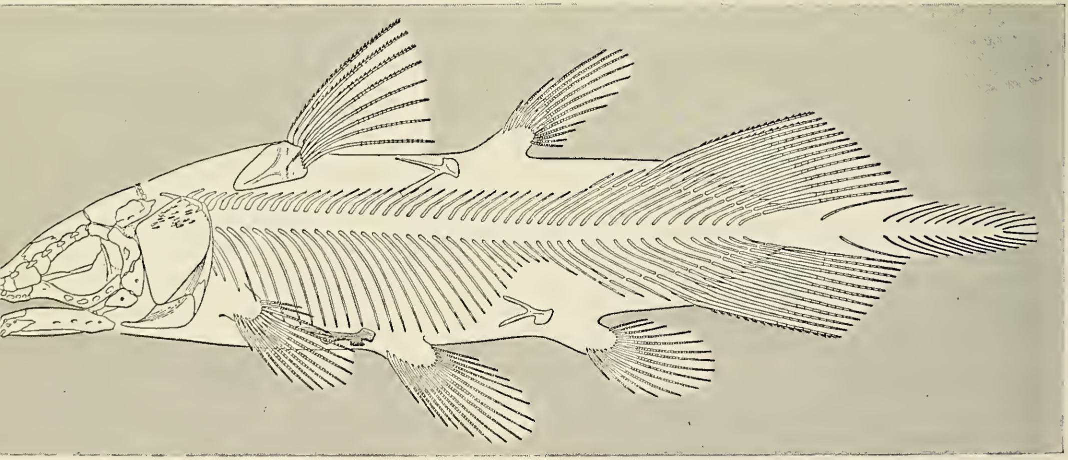
Although Mantell had no way of knowing it, he thereby—and accidentally—provided the first published report of a coelacanth. *Amia* is *not* a coelacanth, but a rather primitive, ray-finned fish (commonly called the bowfin), which is to be found living today only in the fresh waters of central and eastern North America. Fossil remains of the bowfin occur in Tertiary deposits in this country and also in Europe, and Mantell based the identification of his specimen on a fossil *Amia* described by Cuvier from France. Since few fossil fishes had been described by 1822, and their affinities were poorly understood, Mantell's mistaken identification is easy to understand.

The next important step in the history of the coelacanths was taken by the father of paleoichthyology, Louis Agassiz. In the second volume of his famous *Recherches sur les poissons fossiles*, published in 1843, Agassiz set up a new family of fishes, including forms in which the neural arches and spines appear to be hollow in the fossil state. The name he gave this family was Coelacanthidae, meaning "hollow spine." Therein, Agassiz placed several genuine coelacanths—as well as some quite unrelated fishes. In the process, Mantell's *Amia lewesiensis* was renamed *Macropoma mantelli* (after its discoverer).

Paleontologists continued to have a rather vague and indefinite understanding of the coelacanths until the group was studied by Thomas Henry Huxley, one generation later. In 1861 and again in 1866, Huxley provided the first really scientific definition of the group. But it was an American paleontologist, Edward Drinker Cope, who, in 1871, provided the basis for the proper classification of the coelacanths. Cope proposed a threefold division of the higher bony fishes, partly on the basis of fin structure. He called these divisions the Actinopterygii, Crossopterygii, and Dipnoi, which, in the vernacular, are the ray-finned fishes, the lobe-finned fishes, and the lungfishes. The ray-finned fishes have a much reduced, internal skeleton in the paired fins, and the muscles moving the rays are restricted to the fin base. The lobe-finned fishes and the lungfishes have a somewhat different segmented internal skeleton that extends into the paired fins from which the rays radiate. The fin musculature, attached to this skeleton, forms a fleshy, scale-covered lobe on the proximal part of these fins.

The coelacanths, both fossil and recent, are obviously lobe-finned fishes. Indeed, along with one other kind of lobe-finned fishes, called the rhipidistians, they are the only groups in the category Crossopterygii. These technicalities are being reviewed here for good reason: since the discovery of the first living coelacanth, *Latimeria*, in 1938, many people—including some science reporters—have been under the impression that the coelacanths gave rise to the first vertebrates with true legs—the amphibians. Paleontologists have known for nearly fifty years that it is the rhipidistians—and not the coelacanths—that hold the distinction of being the ancestors of all four-legged vertebrates.

When the higher bony fishes evolved from their bony, jawed forerunners, the placoderms—probably about 350 million years ago—they soon separated into two of the groups we have defined: ray-fins and lobe-fins. The lobe-fins, with their very characteristic skull and fin structure, were in turn subdivided into the rhipidistians and the coelacanths, at least by the middle of the Devonian Period, about 300 million years ago. Whether the coelacanths arose from primitive rhipidistians, or both evolved from some common ancestor, is not known. At any rate, the brain case of a Devonian coelacanth is



Reconstructed skeleton of fossil coelacanth of Triassic date.

almost identical with that of a rhipidistian, demonstrating close kinship.

For the specialist and the amateur paleontologist alike, the coelacanth skeleton has distinctive features that make it rather easy to recognize—even as a fragmentary fossil. The skull usually has a sort of "Roman nose" profile. The skull roof is divided into front and rear parts by a wide suture. An important tooth-bearing bone of the upper jaw (called the maxilla), which is present in the rhipidistians and all higher vertebrates, is absent in the coelacanths. The gill region is covered by a large, nearly triangular, opercular bone. There is never any ossification in the region of the notochord, and since the notochord readily decays, it is represented in the fossils by a space between the bony neural arches above and the haemal arches below. The posterior dorsal fin and the anal fin are lobed like the paired fins. Only the triangular anterior dorsal fin has no bones or cartilages extending into it to form an internal skeleton. The pectoral and pelvic girdles and the other fin supports have very characteristic shapes.

The most obvious coelacanth hallmark is the tail. At the end of the notochord, which extends beyond the nearly identical upper and lower tail lobes, there is always a fanlike tuft of short rays. This particular tail pattern occurs in no other group of fishes, living or fossil. Even the scales of a coelacanth have a distinctive structure.

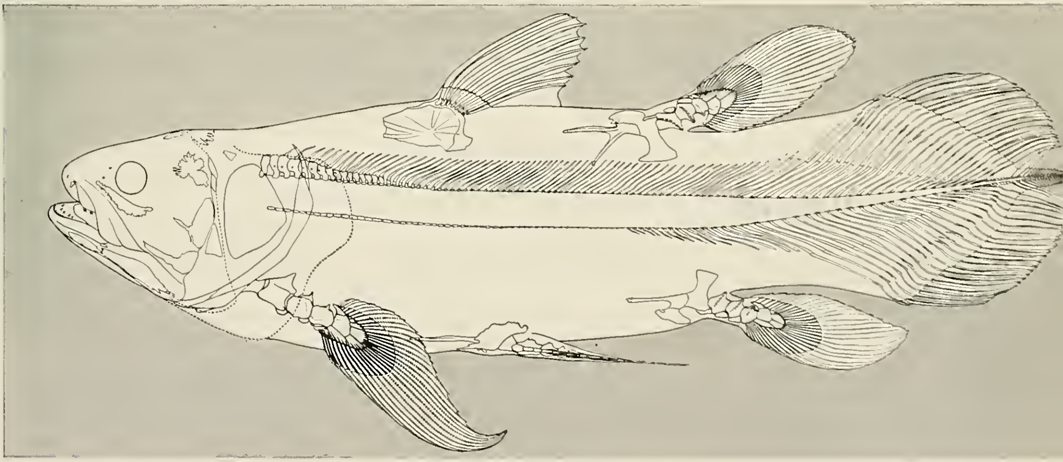
These characters are common to all coelacanths, and they have not changed in 300 million years. Their tendency to remain static during this almost incomprehensible span of time is their most remarkable feature. Before considering the meaning of this phenomenon, let us briefly review certain aspects of this lengthy history.

The first coelacanths, from late Devonian deposits, were typical in all respects except for a rhipidistian-like brain case. By Carboniferous time, there was a marked reduction in the ossification of the brain case. The rest of the story is mainly one of minor change in the skull and the fins. Most coelacanths were either predators (as is *Latimeria*) or possibly plankton feeders, but some Triassic forms developed crushing dentitions. The known fossil genera, about twenty-eight in all, are widely distributed. The pre-Jurassic forms lived in a variety of environments, including fresh-water swamps and lakes as well as the sea. From the Jurassic to the present, these fish apparently were exclusively marine. Specimens have been found on all the continents except Antarctica. The Lower Triassic of Spitzbergen has yielded a number of genera, some of which also occur in rocks of the same age in east Greenland and Madagascar. One Triassic form from Greenland, with the pelvic fins situated forward under the pectoral fins as in the perch, has counterparts in the Triassic of Madagascar and Idaho. The coelacanths were thus world-wide throughout much of their history, and the record suggests that they were most diversified during the Triassic Period.

No fossil coelacanths have ever been discovered in Tertiary rocks, and paleontologists long assumed that they became extinct at the end of the Cretaceous Period. The capture of a living representative in 1938 raised scientific eyebrows all over the world. Where were the coelacanths during the Age of Mammals? A probable explanation is that they were restricted to the permanent ocean basins when the great epicontinental seas withdrew at the close of the Cretaceous. Organisms preserved as fossils in the sediments of the continental shelves or in the bottom sediments of the ocean basins are only occasionally recovered by dredging. The chances of obtaining Tertiary coelacanth remains in this way are remote.

To complicate the problem still more, some time after the Cretaceous—we have no idea when or why—the last representatives of this ancient group apparently were confined to the area around the Comoro Islands, northeast of Madagascar. Since the first specimen of *Latimeria* was captured near the tip of South Africa, it may be surmised that these fishes occasionally move southward along the East African Coast. There is as yet no evidence that they are distributed more widely in the Indian Ocean or that they occur in any other part of the world.

The term "living fossil" has become a trite way of saying that organisms like *Latimeria*, the lungfishes, the tuatara, and the opossum have been around for a long time with very little change. Probably all, or nearly all, of the land animals in this category are well known (there may be a few undiscovered examples among the insects). The discovery of *Latimeria* demonstrates that there are still possibilities in the sea. Within the last few years, a mollusk (*Neopilina*) belonging to a group previously regarded as extinct for about 280 million years was dredged up from the depths of



For comparison: skeleton of *Latimeria*, from Millot and Anthony.

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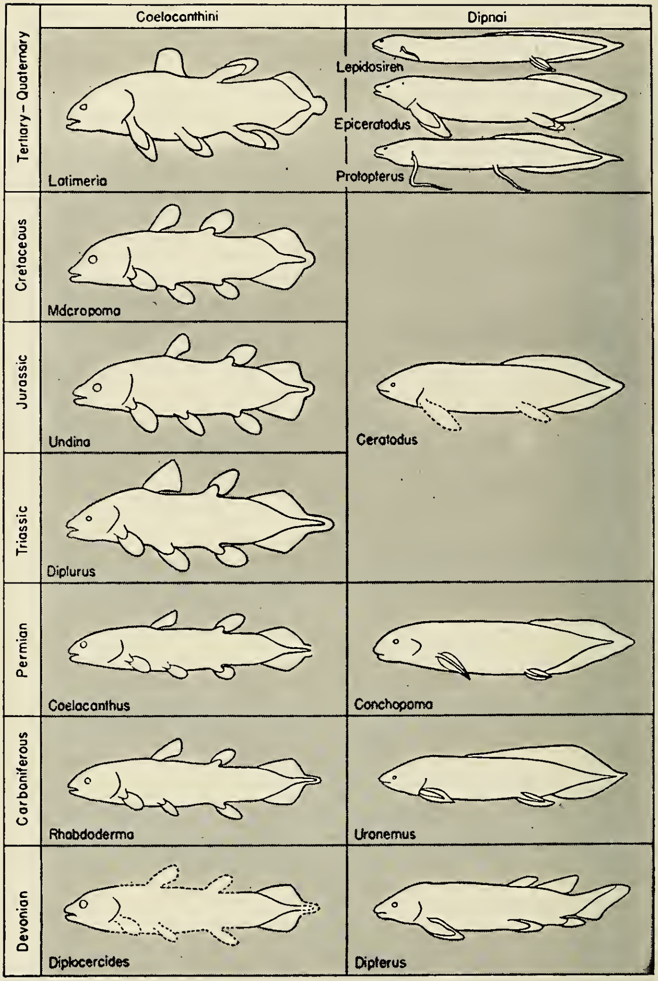

FOSSIL RECORD shows both coelacanth and dipnoan genera to have existed from the Devonian (Paleozoic) to the present. No coelacanth fossils are known in Tertiary.

the Pacific (NATURAL HISTORY, March, 1958) and a crustacean (*Hutchinsoniella macracantha*) discovered in the shallow waters of Long Island Sound (NATURAL HISTORY, February, 1959).

Why have a few kinds of plants and animals persisted relatively unchanged for millions of years? For some, like the lungfishes and *Neopilina*, the explanation is probably that they became well adapted to a particular way of life or to a particular ecologic niche that has also remained unchanged for many millions of years. The lungfishes have been fresh-water bottom feeders since the Devonian, and *Neopilina*'s ancestors apparently found a constant environment in the depths of the ocean. During the Cretaceous, lungfishes existed all over the world: they are now restricted to three areas where there is presumably little or no competition with other types of fishes having similar habits. This inability to meet competition is probably why most relic organisms have restricted distributions.

For millions of years, however, the coelacanths—unlike the lungfishes—inhabited a wide range of fresh-water and marine environments. The physiology and feeding habits of these fishes must have varied considerably, although, aside from minor specializations, these differences are not reflected in the skeleton. In general, the feeding mechanism in fishes is highly adaptive.

Body form and mode of locomotion are related to the feeding habits and are modified accordingly. The great diversity in the structure of the teleost—the most advanced ray-finned fishes—skeletons is clear evidence of this adaptability.

A good explanation for the extreme conservatism of the coelacanth skeleton, in contrast with the teleost, is not easy to provide. One possibility is that this skeleton and its associated musculature (or, to put it another way, the basic feeding and locomotor mechanisms) have *always* been plastic and generalized enough to meet without major changes the requirements of any environment that the coelacanths *successfully* invaded. The common opossum is a good contemporary example of a highly successful and widely dispersed animal that has remained essentially unchanged since the Cretaceous. Perhaps the coelacanths were unable to meet the competition of the ubiquitous teleosts, which had their great expansion during the same period. This could account for the near extinction of the coelacanths and for the restricted occurrence of *Latimeria* at the present time.

THE capture of the first two specimens of *Latimeria* will always be an exciting chapter in the annals of natural history. Professor J. L. B. Smith's ten-year search for the habitat of this most elusive creature is vividly described in his book *Search Beneath the Sea*. With the quest finally concentrated around the Comoro Islands, Professor J. Millot, Director of the Research Institute in Madagascar, obtained ten more adult specimens, including three females. These have been the subjects of an extensive and detailed anatomical investigation at the Laboratory of Comparative Anatomy of the Paris Natural History Museum by Professor J. Millot and Dr. J. Anthony. In 1954, Millot published an album of magnificent photographs of the external features of *Latimeria*, entitled *Le Troisième Coelacanthe*. This volume also includes remarks about the history of the captures, the habitat and diet, and the external morphology.

The skeleton and musculature of *Latimeria* have now been described in a sumptuous volume by Millot and Anthony, *Anatomie de Latimeria Chalumnae*, Tome I (Editions du Centre National de la Recherche Scientifique, Paris), first of a series in preparation on the anatomy of *Latimeria*. Now, for the first time, it is possible to make a detailed comparison of the skeleton of *Latimeria* with the fossil coelacanths. The close resemblance of the individual bones with their ancient counterparts is striking. The description and figures of the

(Continued on page 484)

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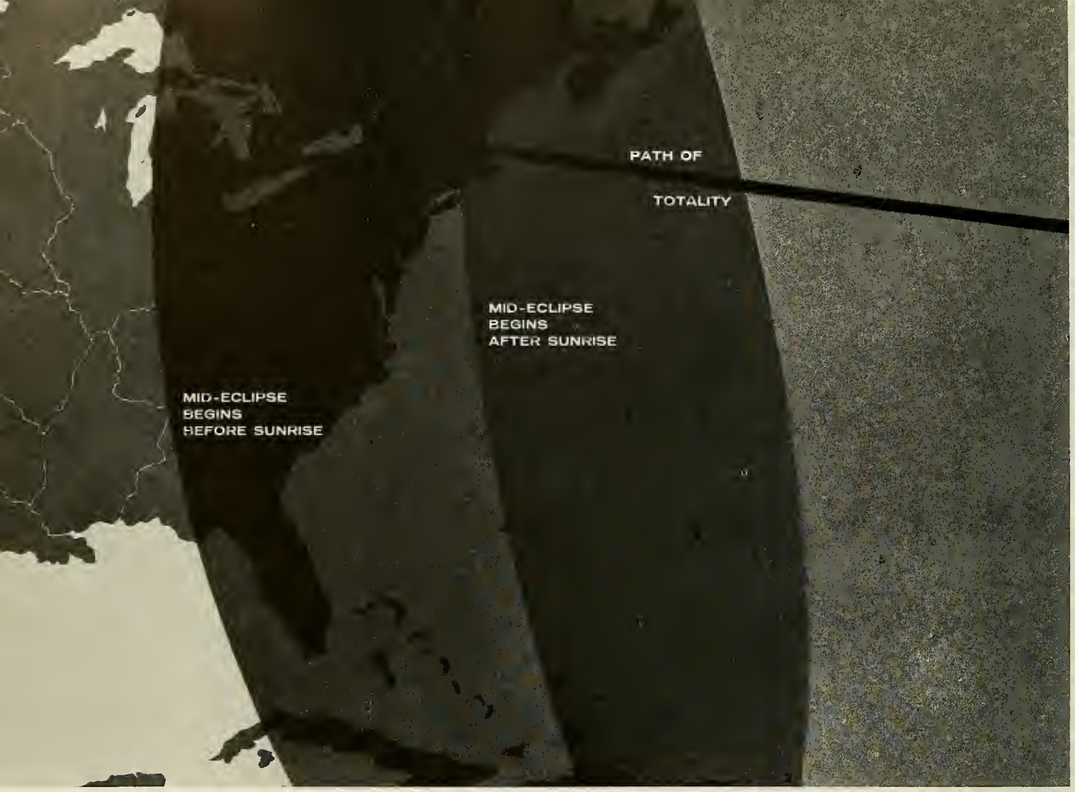


Solar eclipse may be seen in partial phase over wide area of eastern U.S., as shown on map, *above*. Throughout zone at left, from the Great Lakes to Long Island, the moon will be passing from the sun's face at sunrise. In the zone to the right, sun's maximum obscuration will occur at or following sunrise. Dark band, to north, is the path of total eclipse.

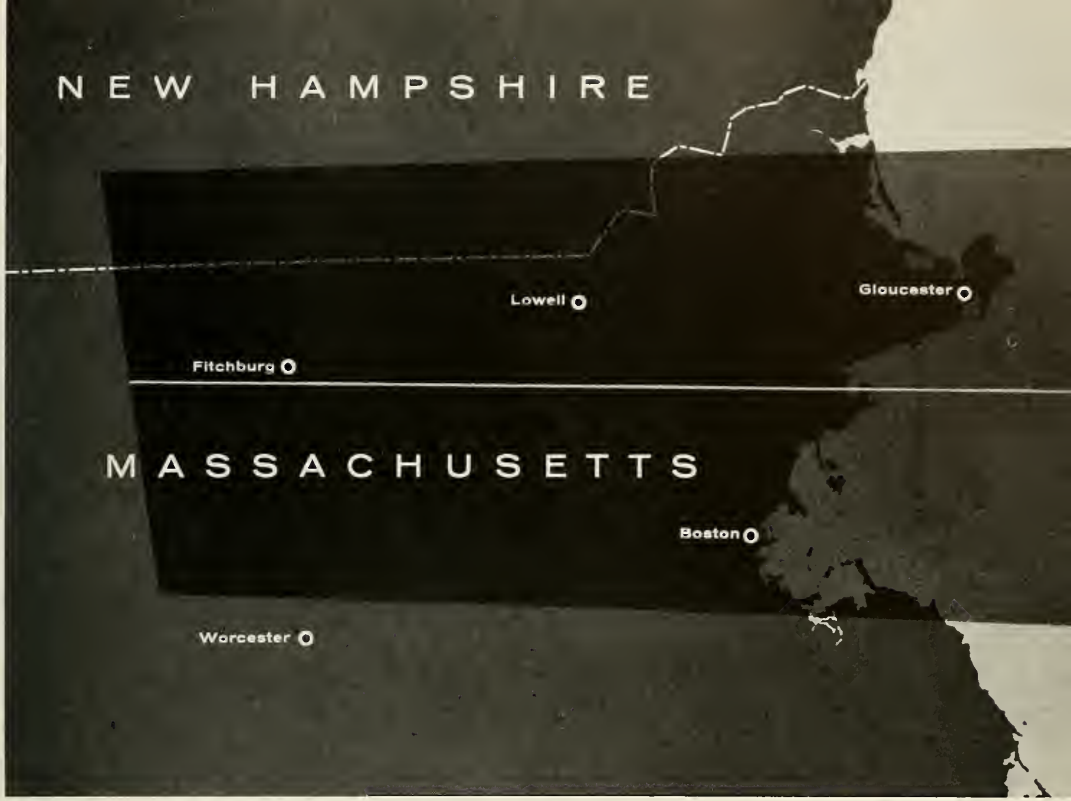
OCTOBER ECLIPSE

At sunrise on October 2, the eastern United States will witness a solar eclipse: herewith, some advice on how to view the event

By Thomas D. Nicholson

Shortly before the autumn sunrise takes place along the eastern portion of the United States on October 2, 1959, a total eclipse of the sun will have begun. The shadow of the moon, as it begins to pass between the earth and the sun, will first touch the earth's surface at a point in the Atlantic Ocean about 800 miles east of Cape Hatteras. There, sunrise will just be taking place: the rising sun will proceed westward, toward the east coast, at the rate of 15 degrees of longitude per hour. By sunrise along the east coast, the October eclipse will be well under way. The eclipse will have ended before the hour of sunrise at Chicago and other places more westerly in longitude. Nonetheless, the event should provide some interesting observations in most of our eastern states (see map, at left, *above*). And those fortunate enough to live or to be visiting in parts of Massachusetts and New Hampshire may see the cream of the event—the sun in total eclipse.

It has been more than five years since a solar eclipse was visible in any part of the United States. The latest one occurred on June 30, 1954, when a total eclipse began in the north central U.S., passed over part of Minnesota, Wisconsin, and Michigan, and then proceeded over the Great Lakes, eastern Canada, and out into the Atlantic Ocean. Like this October's eclipse, only a small part of the 1954 zone of totality, just after sunrise, fell within the United States. This year, the zone of totality in the United States will be even smaller: an area about 65 x 35 miles (see map, at right, *above*).



Land sites in the path of totality lie within shaded area of the map, *above*. Line through the center of area connects points where totality is of maximum duration (about fifty-five seconds). Those who wish to observe the total phase of the eclipse are advised to pick a site, close to this line, that possesses an unobstructed view of the eastern horizon.

This October's eclipse is the second and last solar eclipse of the year 1959 and the only one this year to be visible at all in the United States. On April 8, an annular eclipse of the sun took place in the southern part of the Indian and Pacific oceans, passing through central Australia. This month's eclipse will proceed across the Atlantic Ocean, enter the coast of Africa (about 1,600 miles north of the Equator), continue across central Africa, and end—at sunset—in the Indian Ocean. Over a portion of French Equatorial Africa, where the eclipse will be occurring at noon, totality will last for a few seconds more than three minutes. The duration of totality in that part of the United States where the total phase is visible just at sunrise will be less than a minute.

Both the brevity of the October eclipse and the relative inaccessibility of optimum observing sites limit the opportunities for important astronomical observations. Except in New England and the Canary Islands, off the coast of Africa, the eclipse path lies almost wholly over ocean or over isolated areas of Africa. Most astronomers who plan to observe the event have chosen sites in the Canaries, where the island of Tenerife, with excellent transportation and facilities, lies in a region where the total eclipse lasts for about two and one-half minutes. Weather conditions there are expected to be favorable for these professional observers.

While a welcome opportunity for residents, the New England portion of this eclipse is nearly useless to astronomers. Totality will be brief and the rising sun will be very low over the horizon. At sunrise, the sun is visible, at best, through a thick layer of atmosphere. Refraction, scattering of sunlight, and distortion of the solar image are quite severe, and the sun is badly disturbed by the "flickering" effect of bad-seeing. Despite these professional shortcomings, the eclipse can be an interesting spectacle both for amateur astronomers and for the millions of persons who may simply want to watch one of the most impressive displays nature can produce in the sky. Indeed, some of the very characteristics that make the event nearly worthless for professionals can increase its value to these others. A low sun, totally eclipsed, can result in unusual landscape effects: the colors of autumn, impressive enough in most New England Octobers, may be considerably enhanced by the strange lighting of the eclipsed sunrise. To the eye, the rising sun appears larger and atmospheric effects make it more colorful. Amateur photographers will find many opportunities to combine the eclipsed sun with attractive foreground features. A sunrise eclipse—to the artist, the photographer, or the lover of natural beauty—can be far more attractive than the high, long eclipse more desirable to the astronomer.

The maps on pp. 430-31 show the areas in the United States where the eclipse can be observed. It will be visible in some degree in the entire shaded portion of the eastern United States, and in totality in the area of New England shown on the detailed map. Along a north–south line running nearly along meridian 72° W., the sun will rise at almost exactly the moment of mid-eclipse: the greatest extent to which the sun will be covered by the moon will occur at that time. To the west of this line, the sun will not rise until after mid-eclipse; it will already be emerging from behind the moon as sunrise occurs. To the east of this line, while the eclipse will already be in progress at sunrise, mid-eclipse, the moment of greatest obscuration, will occur after the sun has risen above the horizon.

Both the extent of the sun's obscuration and the length of time the eclipse will last vary from place to place within the area. New York City is just west of the line where mid-eclipse occurs at sunrise. For New York, and its surroundings, therefore, the eclipse will have begun over an hour before sunrise. Nevertheless, the rising sun at New York will appear almost completely covered by the moon, except for a slim crescent of brightness, and it will be about an hour before the sun emerges fully from behind the moon. In general, cities south of New York will see less of the sun covered by the moon as it rises, and the duration of the event after sunrise will be slightly less. West of New York, where the sun is rising later and the eclipse will have progressed further, both the portion of the sun covered and the duration of the eclipse remaining after sunrise will be sharply decreased. At Cleveland, less than half of the sun's diameter will be obscured at sunrise, and the eclipse will end less than half an hour later. At Atlanta, only about fourteen per cent of the sun's diameter will be covered when the sun rises, and the eclipse will end only nine minutes later.

Within the small area of totality in New England, the beginning partial phase of the eclipse will take place before sunrise: at the extreme western edge of this zone, the sun will rise in total eclipse, and begin to emerge from behind the moon almost immediately. Farther to the east, all the events of totality can be seen. Just at sunrise, or shortly after, second contact — the moment when the sun is completely covered — will take place. The entire duration of totality and the ending partial phase of the eclipse will occur with the sun above the horizon. The sun will be at its highest for these events — and totality will be longest in duration — at the eastern portion of the zone, along the coastline. At best, however, the period of totality will begin with the sun only about one degree above the horizon and will only last some fifty-five seconds.

Photography of eclipse, like this 1954 multiple exposure, *above*, requires both patience and careful advance planning.

Those who select an observing site within the zone of totality, or in other areas where the eclipse will be partial, should bear in mind that this is a sunrise event: the sun will be low and just a little south of east when the eclipse is taking place. A high location, with a clear horizon to the east, is to be preferred. Beware of wooded areas, or of rising ground to the east, either of which could obscure the sunrise, the time of which is computed for a sea horizon. Many excellent sites should be available along the coastline, with clear sea horizons to the east. It would be sound practice to visit the observing site early on the day before the event and watch the sunrise. The position of sunrise does not change materially from day to day, so that the circumstances of this prior sunrise will be a good guide to what to expect on the day of the eclipse. The position of the sun, the time it actually becomes visible (as compared with the computed — sea horizon — sunrise time for the area), and the attractiveness of the setting should help in determining the suitability of the selected position. There will be no second chances on the day of the eclipse!

Vagaries of weather — the bane of eclipse-viewers, professional or amateur — appear to be unlikely. Autumn weather, both in New England and in the entire region where the partial eclipse will take place, is generally quite good. Observers in the zone of totality who select sites along the coast, to obtain the highest sun and longest eclipse, will necessarily risk the early morning haze which sometimes develops over water areas. But, even in inland areas, a ground haze could spoil the event.

Whether the reader plans to visit the zone of total eclipse or intends to watch from home, where the eclipse may be partial, normal precautions *must* be followed. The partly eclipsed sun has the same intensity as the sun unobscured: its brilliance may cause permanent damage to the eyes unless its light is filtered. Camera film that has been heavily exposed and then developed can provide an excellent filter, but such film should be pretested to make sure that it is sufficiently dense to afford the protection needed. Three or four sheets of

Mr. Nicholson, staff member of **The American Museum—Hayden Planetarium**, is a regular contributor to **Natural History** on astronomical subjects. Last June, he wrote an account of the celestial influences that affect the tides.

such film should be placed together at first to test effectiveness: they can be discarded one by one until a comfortable and safe filter is obtained. Again, it is wise to do this the day before the event, to be sure your filter is adequate: if it is satisfactory with the naked sun, it will also be satisfactory during the eclipse.

The filter should be put aside during totality, of course. When the sun is completely covered by the moon, only the faint light of the corona — the sun's thin, outer atmosphere — is visible to the naked eye. If conditions are favorable, the observer may also be able to see the red-colored prominences that occur at the edge of the sun, quite close to the dark, obscuring disk of the moon.

Use of a telescope enhances this spectacle considerably, allowing the observer to trace delicate detail in the sun's corona and to see more clearly any prominences that may lie along the edge of the sun. Even binoculars will increase the observer's opportunities. But such optical aids must be used with extreme caution. Under *no* circumstances should telescope or binoculars — or even opera glasses — be used to watch the partial phases of the eclipse, unless adequate protection is provided by the application of pretested filters.

Many observers will, of course, wish to photograph the eclipse. A few general guides may be useful. For one, the camera lens — like the eye — *must* be filtered to obtain a clear image of the partially eclipsed sun. There is too much light from *any* portion of the sun for film as well as for eyes. Neutral density filters, such as Kodak Wratten, with densities of 3.0 to 5.0, are effective. Again, it is well to make test photographs of the unobscured sun on an earlier day — trying various exposures with filter, film, and camera — to achieve the desired results. But again remember that, during totality, no filter is needed and none should be used.

To capture the image of the fully eclipsed sun, the lens should be wide open. Various exposure times will give various results. In general, the longer the exposure time, the greater will be the extent of the corona captured by the film. Short exposures will show only the bright, inner corona; long ones will show the fainter streamers, farther out from the sun's edge. For exposures longer than 1/25 s., tripod or other mounting is mandatory. And, since the sun is in motion, exposures longer than one second should be avoided unless the camera mount is guided.

During totality, there is insufficient light to obtain a photographic image of the foreground along with the obscured sun. The best opportunities for honest pictures combining landscape and the sun come during the minute before totality begins and the minute after it ends. Wide-open exposures at these times *should* catch the landscape and a reasonably good image of the sun as well.

With a normal lens, the size of the sun's image on the film will be disappointingly small. Generally speaking, the image will be only 1/100 of the focal length. Thus a 5-inch lens will produce a sun about 0.05 inches in diameter on the film. If this image is sharp, of course, it can be enlarged considerably. But lenses of good quality, with greater focal length, are preferable for pictures aiming to show the structure of the corona when the eclipse is at its total phase.

One intriguing project for the ambitious photographer is to make a sequence record of the progress of the eclipse. This can be done, whether the observer is in the zone of totality or only in an area of partial eclipse, by exposing a single film at periodic intervals throughout the time of the eclipse. The camera must be sighted exactly toward the position of sunrise, and mounted firmly. The lens — appropriately filtered — should then be opened briefly every five minutes from sunrise until the eclipse has ended. But *no* filter should be used at totality. Again, such a sequence should be tested *before* the event on the naked sun so that both camera position and exposure times will be known on eclipse day.

One other precaution, especially important for a sunrise eclipse. Be sure to set the alarm clock correctly, and answer its call promptly! More than one eager would-be observer has slept through the event for which he planned so carefully. Many events can be postponed but not an eclipse. The sun and the moon move on.

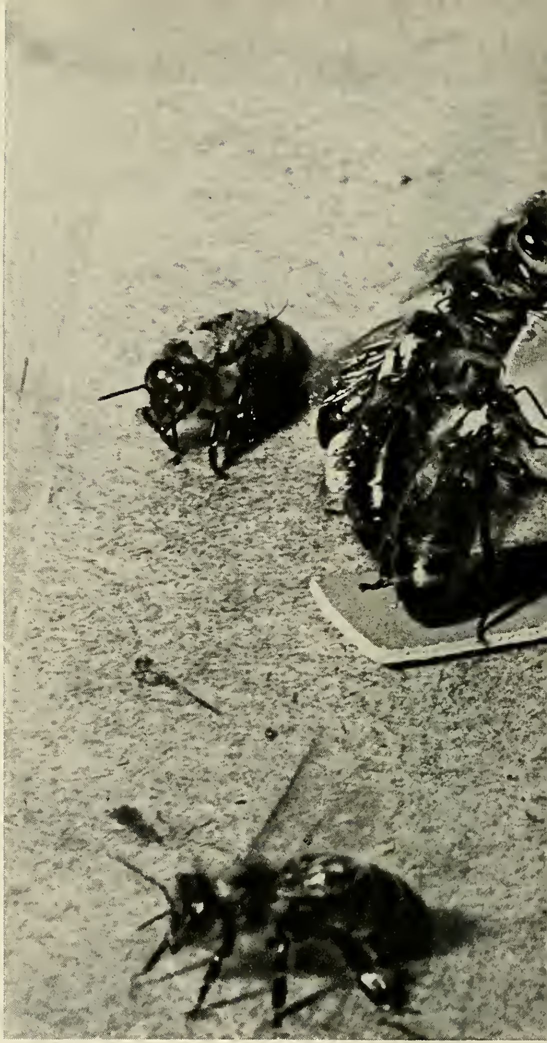
Brief though the October eclipse will be, it is our last opportunity within the United States to observe any solar eclipse at all before 1963. And even this date is an accident of history. A few months ago, "before 1963" would have read "before 1970," the year in which a total eclipse of the sun will pass through central Florida. But with the addition of Alaska, as our 49th state, July 20, 1963, becomes our next solar eclipse date. On that day, a total eclipse of the sun will pass right through the center of the largest — and next to newest — of the United States.

Viewing the eclipse requires eye protection. Sun glasses, *above*, are inadequate: sheets of exposed film are superior.

THE CLOCK OF THE BEES

The time sense of these insects proves to be internally controlled

By MAX RENNER



NOWADAYS, if we resolve to do something at a certain time, we seldom rely on our time sense. One glance at a clock or watch suffices to tell us how many hours of the current day have already become part of the past. Or, if we know the compass and something about astronomy, we can orient ourselves in time without a watch by looking at the sun by day or the moon by night. Assume we know that the sun stands in the east at 6 A.M., in the south at noon, and in the west at 6 P.M. Then, when we see the sun in the southeast, we know the time must be about 9 A.M., or about 5 P.M. if the sun's position is west-southwest.

If we want to wake up during the night at a predetermined hour, without the help of an alarm clock, it is more difficult. Many people cannot do this with any reliability. But the number of those who can do so with precision is not so small as one might assume. Before going to bed, these people simply resolve to wake at a certain hour. Seldom does their "internal clock" deceive them by more than a quarter of an hour. Today, few persons depend upon this mysterious ability, since alarm clocks are common. But until late in the past century many farmers, hunters, and fishermen depended upon such internal clocks.

It has been known for a long time that not all men are equally endowed with this ability to wake up at a predetermined time. It has also been known that a certain concentration of mind is required if the determination to waken is to be successful. The various methods developed by different peoples indicate the extent to which mankind has been occupied with this problem. Take a few examples from Germany. In the Spreewald, a man would grasp his big toe after going to bed, concentrate on the predetermined hour, and repeat to himself: "I want to wake up at [such and such an hour]." In the Rhineland and Westphalia, he who wanted to awake at four o'clock stamped four times under the bedstead. The farmer in central Germany knocked the number of the hour against the wall of his bedroom: the Bavarian farmer rapped it out against his bed-post.

Naturalists know that animals divide their days, too. In their habits they are, of course, bound to the changes of night and day. During daylight, the "day animals," such as our songbirds, are active, while during the hours of darkness the "night animals," such as owls and many rodents, go about their business. When the one group is active, the other rests. Yet, it is a mistake to attribute this rhythmic behavior exclusively to the rhythm of day and night; that is, the presence or absence of light. Such animals will also maintain their characteristic rhythm under continuous artificial light or in continuous darkness.

How is this possible? Does the animal orient itself in time through external influences that are perceivable even in illuminated or darkened rooms? Or does the animal possess something like man's internal clock? In what follows, we will not attempt a broad discussion of this intriguing problem, for this would demand a recitation of all that we know about diurnal rhythms and orientation in time of many different animals. Instead, we shall limit our examination to the behavior in the honeybee that is especially

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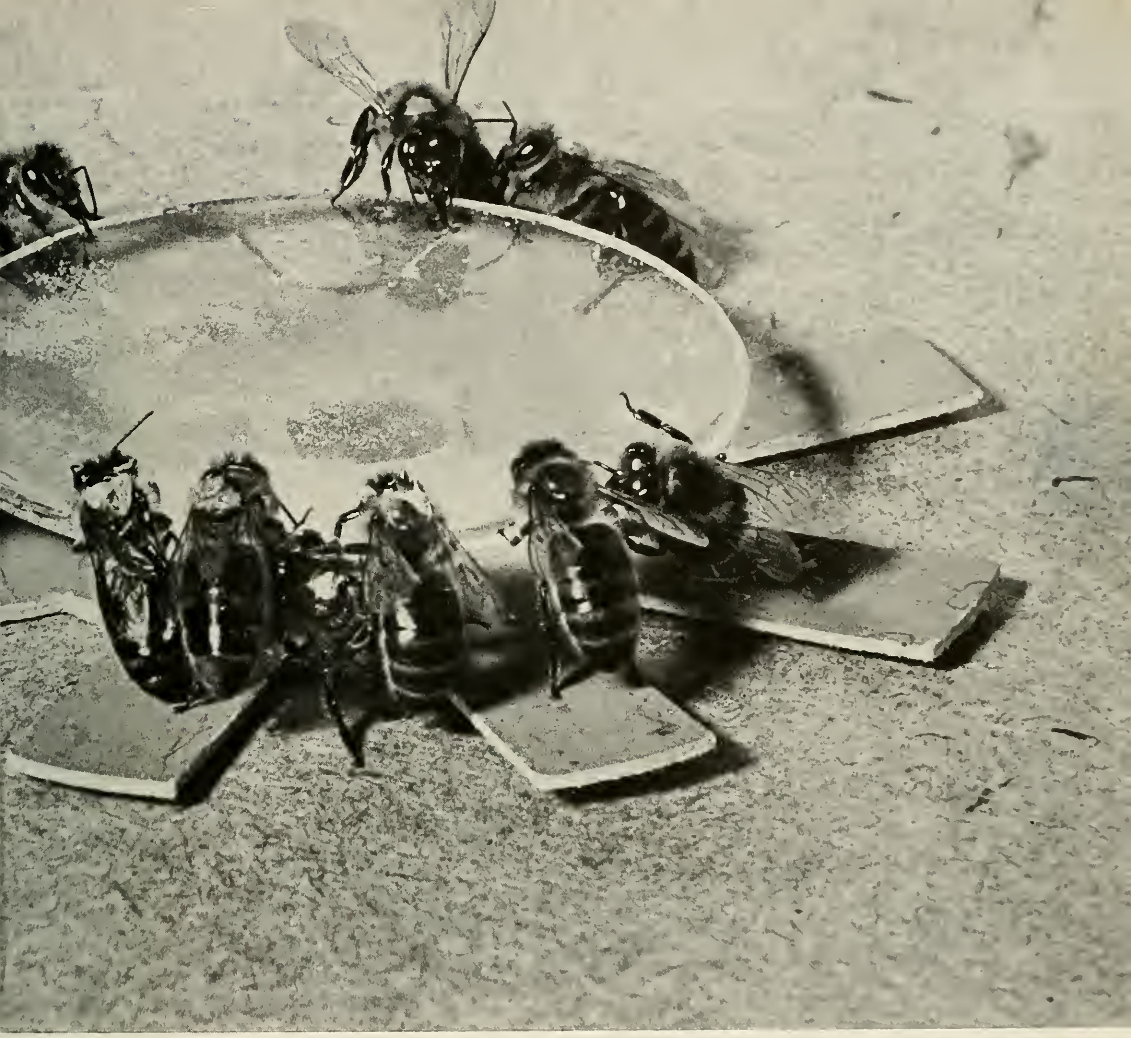
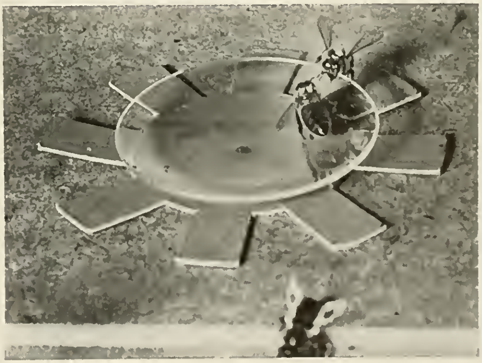
DR. RENNER, a student of the eminent Karl von Frisch, is on the staff of the Zoologisches Institut in Munich, where his research centers on the behavior and biology of bees.



Bees in training are fed, *above*, at same hours every day. Food is absent in test, *below*, but bees return on schedule.



related to our problem. The bee's ability to orient itself in time has been thoroughly investigated because it was the observation of its behavior that first gave rise to an exact examination of this whole problem.

Some fifty years ago, the Swiss physician and scientist August Forel observed that the bees that frequented his porch every morning, to nibble from the sweets on his breakfast table, would appear at the usual time looking for the coveted food, even when there was none. Forel concluded that the alluring effect of the smell of the sweets (or any other stimulus emanating from them) could *not* have been the cause for the timely visit of the bees. Some simple experiments confirmed his conjecture. "The bees remembered," Forel concluded, "the hours at which they had usually found sweets. . . . They have a memory for time."

A few years later, another scientist, von Buttel-Reepen, called this remarkable ability "time sense." He observed that the fragrant, richly colored buckwheat fields were only frequented by bees until about 10 o'clock in the morning — the same hours during which the buckwheat flowers secrete nectar. Even though smell and color were the same in the afternoon, no bees were then to be seen. Yet, at an early hour the next day, hundreds of thousands of these industrious insects turned up again to collect the buckwheat nectar for as long as the sources flowed.

Evidently, the bees had quickly learned that the buckwheat flowers secrete nectar only at certain hours. Therefore, they did not start out on what would have been vain flights during the nectarless hours. Only the assumption that the bees possessed a time sense could, in Buttel-Reepen's opinion, explain this highly practical behavior.

Today we know that the conclusions of both scientists were correct, although their evidence was not compelling. The work of the zoologist Karl von Frisch has familiarized us with the "language" of the bees. He has shown that worker bees, having found a rich source of nectar, can by means of their dances induce many of their hive-fellows to join them in a collective flight to the source.

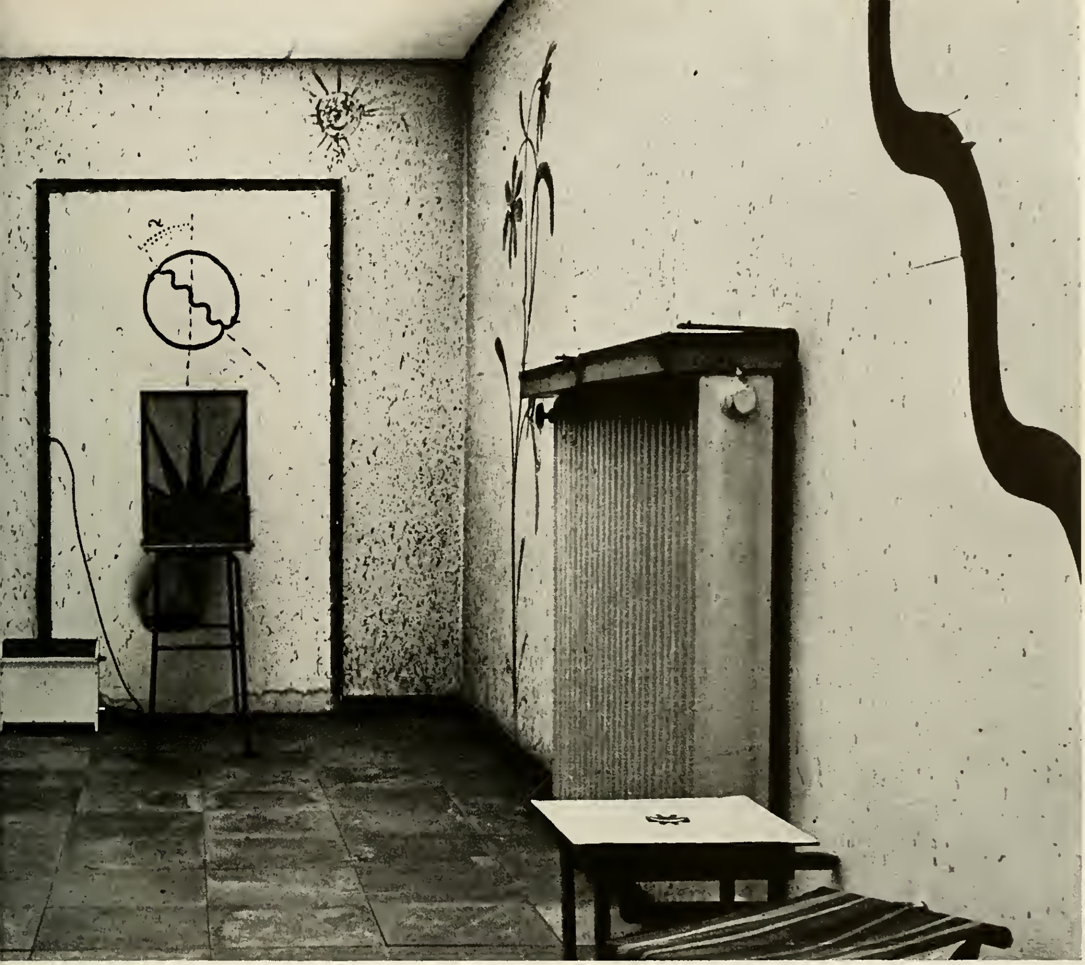
If only a few scouts, which could well escape the eye of even the most careful observer, had reconnoitered Buttel-Reepen's buckwheat fields from time to time during the nectarless hours, for example, they could have alerted their hive-mates quickly as soon as the nectar flowed again. Forel's experimental arrangement, to be sure, excluded such a possibility. He could overlook his porch: if even a few bees had come there except at breakfast time, they would have been noticed. There is, however, an explanation other than time sense for their punctuality. It is possible that Forel's bees connected the position of the sun — or some other phenomenon of the daytime hours — with the experience of a rich food source, and thus oriented themselves in time. In other words, they would have flown to Forel's porch when the sun's position was the same as at breakfast time the preceding day. Such behavior would not demonstrate a true time sense. Rather, it would prove the bees' ability to connect — for the purpose of their orientation in time — certain experiences with events recurring periodically each day. We could speak of a true time sense only if their orientation in time would function after all such possible factors of daily rhythm had been excluded.

Whether bees have such an *internal* time sense (that is, an "internal clock"), or whether they find out about time by *events recurring periodically each day* (that is, by an "external clock"), has occupied a number of research workers since 1929. In that year, Ingeborg Beling, a student of von Frisch, subjected the ability of bees to orient themselves in time to an exact analysis.

For a proper understanding of what follows, it is necessary to acquaint the reader with the method worked out by Miss Beling, a method that has been adopted by all later researchers. Twenty to thirty nectar-collecting bees, numbered individually by dots of color, are fed sugar water at an artificial feeding place for several days — each day from about 10 A.M. to noon. For the rest of each day, the bowl containing sugar water is empty. Bees looking for food before 10 A.M. or after noon return unsuccessful to their hive. After six or eight such "training" days, the feeding station, while otherwise unchanged, is left empty all day long. On this "test" day, an observer, sitting next to the station, notes both the time of visit and the identity of each bee that comes to the bowl.

Single bee colony lived in a special room for five years. To control local environment, neon ceiling lights, covered

It is surprising to see how exactly the bees have learned the training hours — not only the start of the feeding period but also, and even more exactly, its end. Almost precisely at the appointed time, they appear at the feeding station to search persistently and intensively for the coveted sugar water. On a test day, the observer might judge by their behavior that the bees cannot "believe" that the table has not been laid for them as usual. Over and over again, they come flying, run round searchingly, stretch out their proboscises into the bowl to reassure themselves that there is really nothing sweet in it. The most industrious ones among them extend their searches after a while to the wider environment and lick all glittering objects — such as the watch and the pencil case of the observer — and some especially audacious ones will even poke their proboscises into



by transparent paper, were kept constantly lit, temperature was maintained thermostatically. Hive is at rear, feeding station at lower right, pollen tub on the left wall. Drawings on walls and hive entrance aided bees' orientation in room.

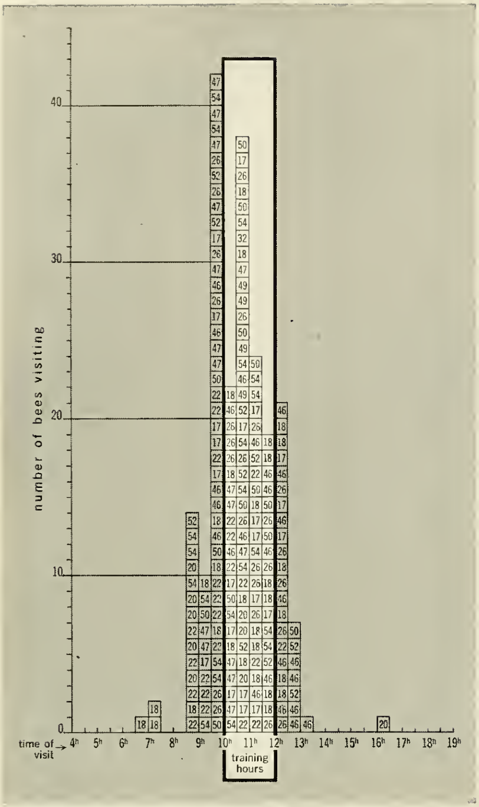
the wrinkles of the note-taking observer's bent hand. When the usual time of feeding comes to an end, the bees' visits become rarer: hardly half an hour later, the feeding station is deserted and quiet.

At the beginning of the training period, the bees are less punctual. Frequently they arrive a little beforehand — a behavior that has yet to be cleared up. In its effect, however, this behavior appears to be expedient, for "early bird" collectors can start to work quickly and in full strength as soon as the source of food begins to flow.

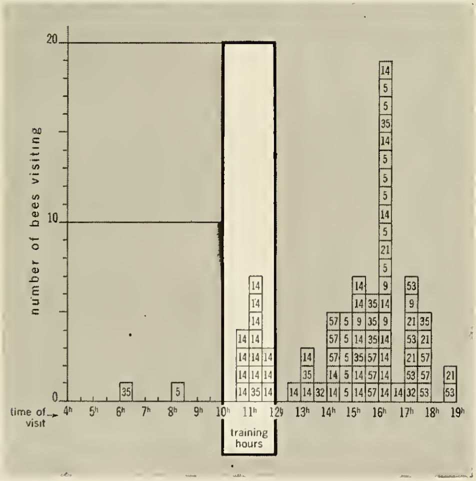
The next step in these studies was to eliminate the effect of those environmental phenomena that recur periodically during the day — for example, the position of the sun or temperature variations — that might function as time indicators. To accomplish this, a bee colony was placed for its training period in a specially devised room. This experimental room was kept at a constant temperature, and its illumination was constant both day and night.

A man would very soon lose any orientation in time under such circumstances: the bees, however, appeared punctually at the feeding place. They were not reading the time from the position of the sun or the brightness of the day. As subsequent studies established, neither the electrical conductivity of the air nor cosmic radiation (which both show a daily rhythm) served them as an external clock. In the gallery of a salt mine, some six hundred feet below the surface of the earth, where neither of these factors is effective, training was successful. Thus, it appears that the clock of the bees works independently of periodically recurring influences of the day.

There is, however, one problem. Can we be sure that *all* external factors, which might function as time indicators, have been eliminated in these "bee room" tests? Before attempting an answer to this question, we should acquaint the reader with the results of some other experiments.



After training, bees will visit empty feeding dish regularly, as graph, *above*, shows. Black lines enclose visits during hours for which bees were specially trained. Number in each box is identification number of the individual bee. Five hours of refrigeration at 4°–5° C. slowed bees' metabolism. *Below*, most visits to dish came at appreciably later time.



One possibility that soon comes to mind — namely, that the clock of the bees is nothing but a hunger rhythm — has, of course, been taken into consideration, even though this appeared to be improbable from the outset. Worker bees do not take nectar — or sugar water — as direct nourishment. Rather, they fill their honey bag, an extension of the esophagus. After their return to the hive, the honey bag's contents is regurgitated and turned over to other worker bees, which store it in the cells and process it until it has ripened into honey after about two weeks.

Therefore, the training period is not a feeding period for the collector bee, in the sense of a "meal," although we frequently and incorrectly call it just that. It is true, at the same time, that the collector bees will also take nourishment; for he who works must take nourishment, too. But — and this was proven by exact investigations — the collectors also nourish themselves when they are *not* collecting—that is, whenever they are hungry. Nonetheless, the hunger-cue possibility was investigated with scientific exactitude: it was found that the time sense of the bees is definitely not governed by a hunger rhythm.

How then do the bees remember time? Do they keep in mind the *time of day* at the beginning and at the end of the training period? Or do they, instead, register the *interval* between two successive training periods? The result of experiments made to arrive at an answer to this question was surprising: the time memory of the bees is inseparably bound to an interval of twenty-four hours.

All attempts to train bees to a periodicity distinctly different from this — for example, to induce them to come to the feeding table every nineteen or every twenty-seven hours — were not successful. While the results of other experiments at first seem to contradict this finding, closer observation makes it clear, that these seeming contradictions actually confirm the twenty-four-hour periodicity. Training the bees to come two or more times in one day — no matter when these times are — is possible without any difficulty, if only the intervals between successive periods are not less than two hours each. In contradistinction to the unperiodical, nineteen-hour or twenty-seven-hour training, the training hours in these latter cases recur at the same time each day. It is, therefore, a matter of two or more training periods in the twenty-four-hour rhythm fitted into one another (the physicist would refer to "shifted phases").

But our initial question — whether bees recollect times of day by means of an external clock or an internal one — has still not been answered. The fact that bees are bound to a diurnal rhythm, while seeming to justify the assumption of an external time indicator, does not prove it. An *internal* twenty-four-hour clock, situated perhaps in the metabolic system, could achieve the same effect. In that case, metabolic changes would also alter the time sense: that is, increased metabolism would result in the bee's clock being fast, decreased metabolism in its being slow. Experiments have proved that bees are late at the feeding table by several hours when they are put in a refrigerator after the last training period and kept there for five hours at a temperature of 4°–5° C. After a short time, they are completely stiff and numb: their metabolism is substantially decreased. Back in a warm temperature, they thaw in a few minutes and return without any visible damage to the hive. However, parallel attempts to induce the bees to come to the feeding table ahead of schedule — by giving them drugs to accelerate their metabolism — have had no success. Yet, the experiments with cold proved the dependence of the bees' time orientation upon organic factors.

To believe that this finding is conclusive proof of the existence of an internal clock, however, is to forget that the cold could have done no more than paralyze the bees' ability to perceive an external time indicator. Indeed, until recently, the possibility could not be excluded that some external factors not yet taken into account — such as the gravitational force of the sun and the moon, recurring periodically each day, or even some factor completely unknown to us — play a role in the bees' time orientation. The problem seemed insoluble. How could factors that were unknown be positively eliminated?

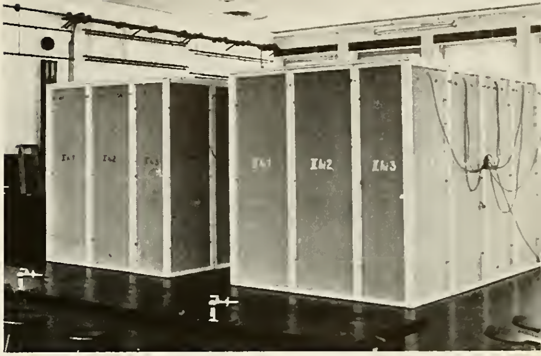
Still, there was a solution. It was pointed out by von Frisch as early as 1937. His considerations were the following: all environmental phenomena that show a daily rhythm derive their periodicity, directly or indirectly, from the rotation of the earth. These phenomena, including the elevation of the sun, occur at places of different longitude on the earth at different times, corresponding to the local time zones of each area.

This being known, the following experiment would provide a definite answer to the question concerning the nature of the time sense in bees: they would be trained in one local time zone for a period and then tested in another local time zone. If environmental phenomena are decisive, they would come to the test dish either *before* or *after* the twenty-four-hour period — that is, twenty-four hours minus or plus the difference in time between the two local zones. If, on the other hand, their time sense does not depend upon external factors but is governed by an internal clock, which maintains its twenty-four-hour rhythm, they would come to feed as usual — exactly twenty-four hours after their last training. The following description of such a relocation experiment, conducted in the summer of 1955, illustrates these theoretical considerations.

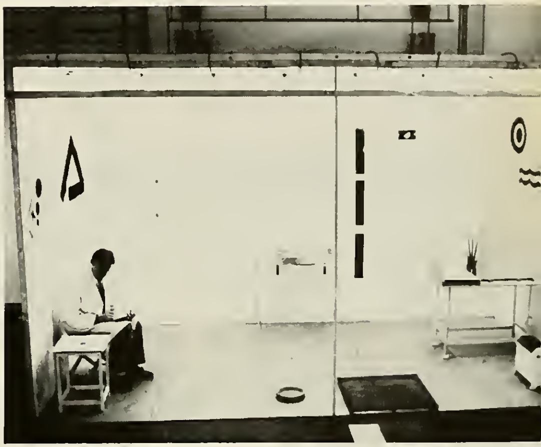
In this age of air travel, it is possible to transport a bee colony a great distance in a short time. Because of their favorable air connection, Paris and New York were selected as the two local areas: the bees could be trained in a bee room on one side of the Atlantic and tested on the other. The difference in time between New York and Paris is large enough to make for an indisputable result. Two identical — and portable — experimental rooms, were built in Munich and one sent to Paris and the other to New York. Forty bees were trained in the Paris bee room under conditions of constant illumination for the period of 8:15 to 10:15 P.M., French Summer Time. After a last training, the hive was packed into a box and flown to New York on June 13/14. Not quite twenty hours later, the hive was set up in an identical New York bee room.

The observer sat expectantly next to the feeding table. When would the bees come to the bowl? Twenty-four hours after their last training (which would be between 3:15 and 5:15 P.M., Eastern Daylight Time), or at the local New York time corresponding environmentally to the time of training in Paris — between 8:15 and 10:15 P.M., EDT: that is $24 + 5 = 29$ hours after their last training? Would they come at all, or had the long air journey from one continent to the other disturbed them so much that their memory for time and locations had suffered?

The bees did not take long to answer these questions,



Identical bee rooms were built in Munich. One was sent to Paris, where bees were trained, the other to New York.



Interior of room, with side wall removed, shows beehive on small table, *right*, and training area near observer, *left*.

Trained bees were flown to identical New York room, and began feeding twenty-four hours after last Paris training.

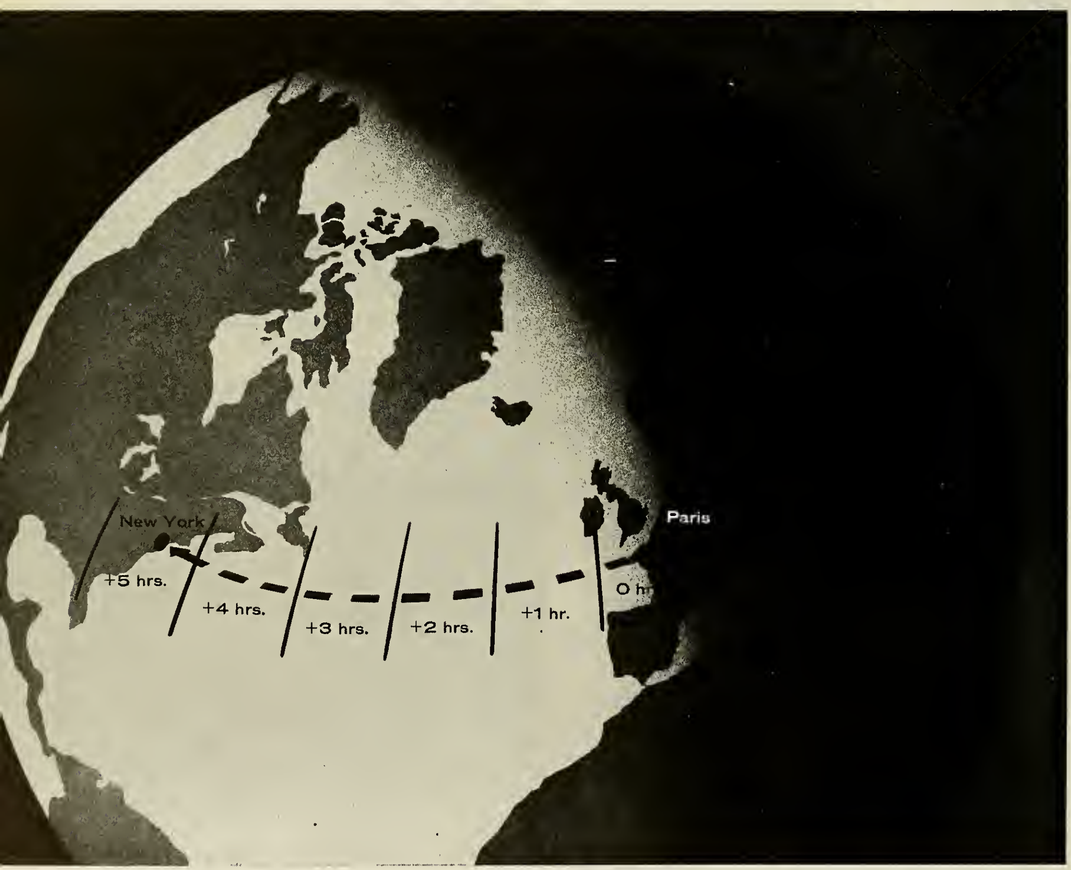
and they answered in the clearest possible way. At 3:15 P.M., EDT, the first bees came out of the hive and started flying about the room, as if their location had never changed. And the ensuing visits to the feeding place were so numerous and thorough that it was difficult for the observer to note down each visitor correctly.

The result of this experiment, as well as the reverse one (training in New York and testing in Paris), has clearly answered the question as to the nature of the bees' orientation in time: the trained collector bees maintained their twenty-four-hour rhythm, independently of external influences that periodically recur during the day. Bees have an *internal* clock, governed by their organism.

It may be asked what purpose the time sense of the bees fulfills? Even if some plants, such as buckwheat, secrete nectar only in the morning, there are certainly others that secrete nectar during the noon hour or in the afternoon. True: bees could certainly collect nectar without their time sense. But with it, their daily activities become easier and more rational and, as we know, everything in the bee colony is organized rationally.

The collector bees, which have been exploiting one source of nectar for hours, do not at once desert it when it becomes temporarily exhausted. They make good use of the rest period and retire to a quiet corner of the hive. Far away from the busy intercourse in the area of the front comb alleys, they take a rest from their strenuous work. Only when the hour approaches at which "their" flowers secrete nectar, do they resume their collecting. It would be a waste of honey and energy if they had to fly out for reconnaissance every twenty minutes or so to ensure their arrival at the very time the source would flow again.

Even so, the bees' time sense might still be dispensed with, were it not that the sense is absolutely necessary for the bees' orientation in space – for which they use the sun as a compass. The solar compass, as we saw in our initial examples, can function *only* if the time of day is taken into consideration. And, finally, when the collector bee returns to the hive from a nectar reconnaissance, the direction and the distance of the source is communicated to other workers by means of a dance. For the correct execution and comprehension of this dance, a time sense that works exactly is also an absolute requirement.



TIME-ZONE SHIFT from Paris to New York, with accompanying change in possible celestial influences, did not upset the bees' twenty-four-hour feeding rhythm. Thus, time sense of the bees was conclusively proved to be of internal origin.

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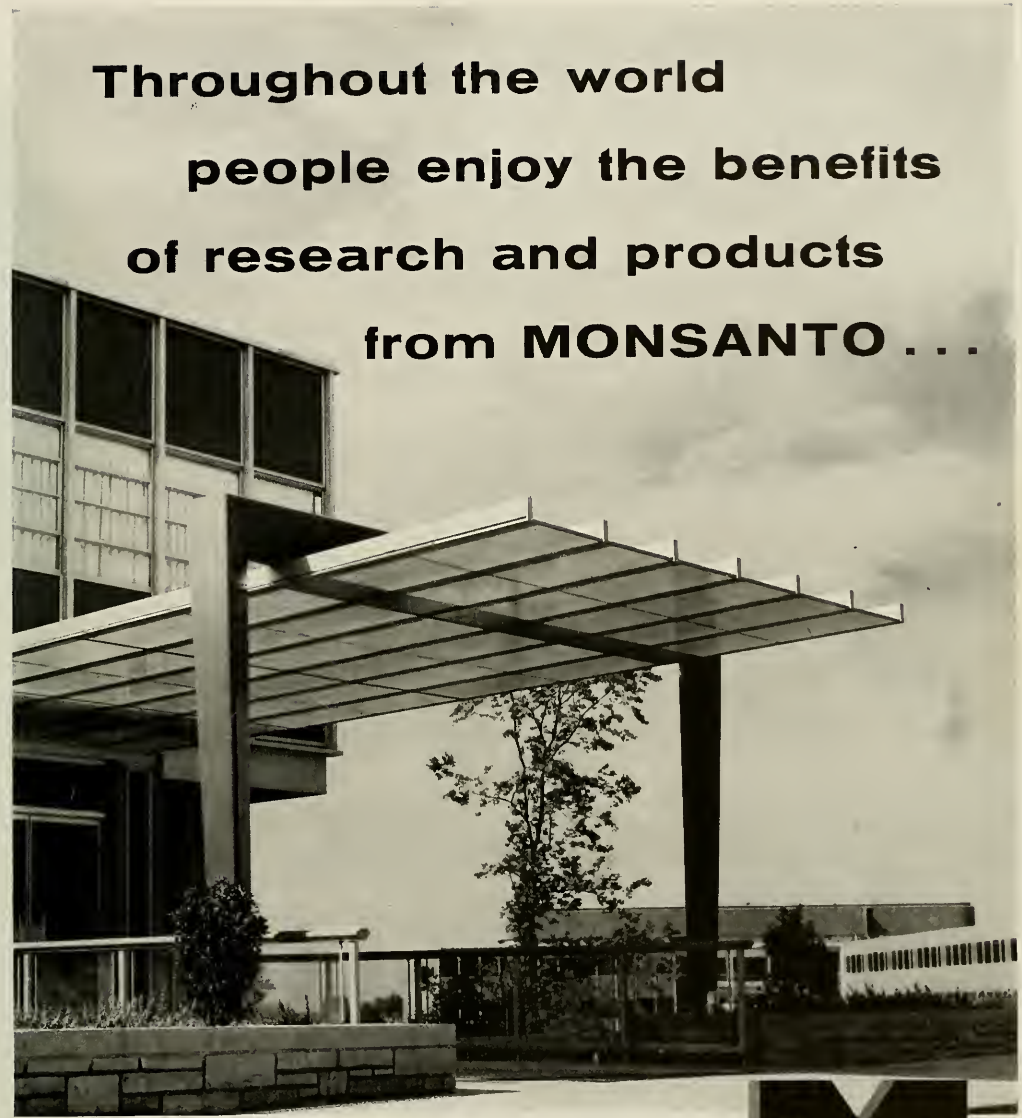

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GOLDENROD GALL

A common autumn flower offers a study in plant—insect relations

By JACK McCORMICK

WHEN THE GOLDENROD blooms in the fall across our middle western and eastern states and in southern Canada, even the most casual observer will notice the prevalence of conspicuous galls, some as large as ping-pong balls, on the plants' stems. These curious growths are caused by a fly—*Eurosta solidaginis*—one of the many gallflies of the family Trupaneidae. This family includes the Mediterranean fruit fly, the fruit maggots, and other serious pests.

In early summer, the female *E. solidaginis* lays its minute eggs on a tender goldenrod stem. About two weeks later, in mid-June, the tiny, wormlike larvae hatch from these eggs and bore shallow tunnels through the outer skin of the plant stem with their digging-hammer jaws. Some of these tunnels are short, but others are of a considerable length. Many end abruptly, an indication that the larva met an untimely death, but some terminate in a minute hole where the larva has turned inward and bored into the center of the stem.

The exact cause of the subsequent formation of a gall is unknown. It is assumed that the excessive growth of the plant stem in the area occupied by the larva is initiated either by the mechanical irritation caused by its presence and activity or by some growth substance it may secrete. In either case, the infested section of the stem grows rapidly from late June to late August. It expands to several times its normal diameter, thus forming the familiar gall, which, however, does not injure the plant. Another insect, a tiny moth larva, also produces stem galls on goldenrods, but these galls are always elongate rather

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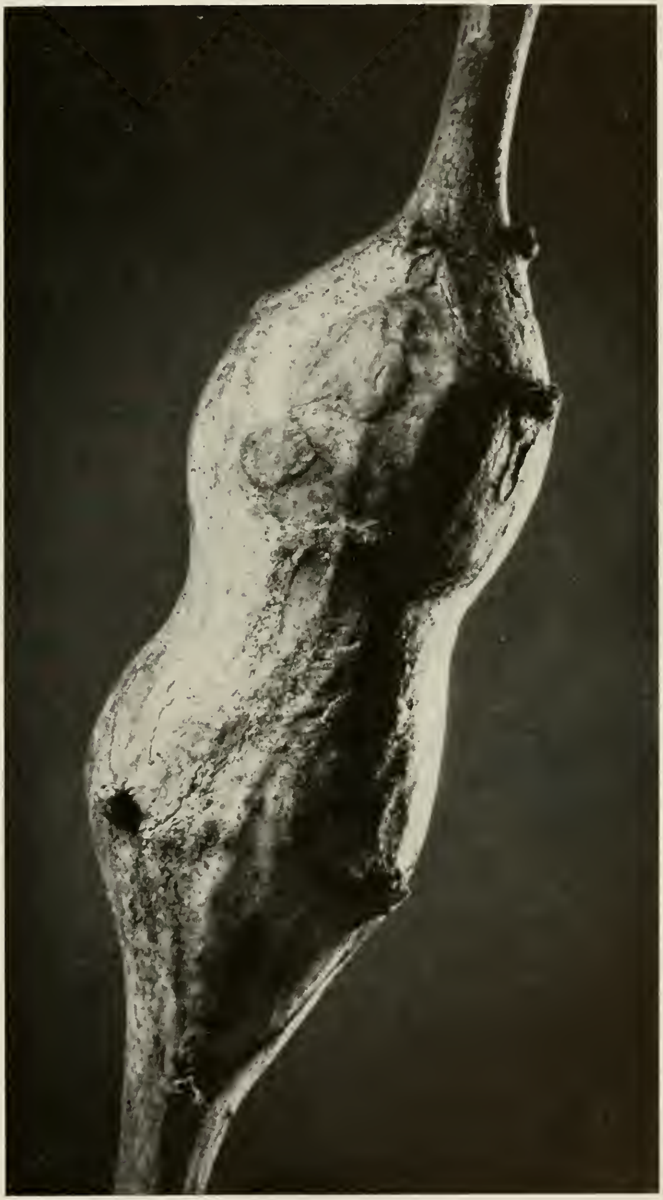
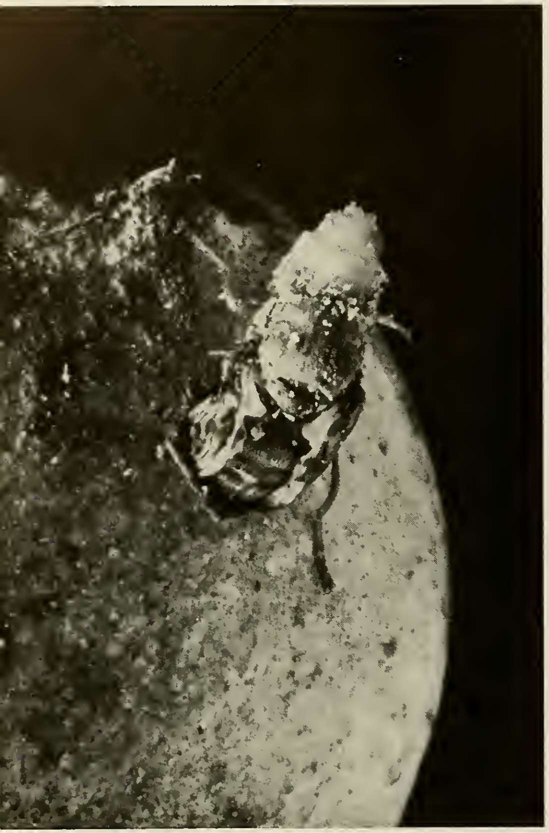
DR. McCORMICK is a plant ecologist who has written widely on botanical and allied subjects. His article is illustrated by photographs taken by GORDON SMITH, a photographer and engineer, who lives in Buffalo, N. Y.

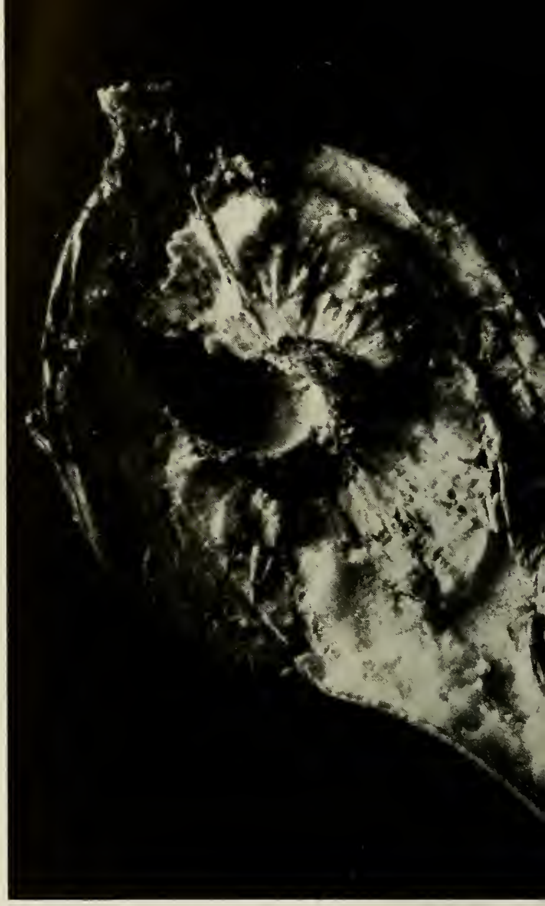


ROUND GALLS occur on stems of many species of the familiar goldenrod, *left*.

COALESCENCE of two stem galls, *above*, has resulted in a spindle-shaped mass.



Bladder-like ptilinum on fly's head inflates and deflates, breaking shell of gall. Fly, *above,* has nearly freed itself.



Opened gall, *above,* is shown to be formed by extra growth of goldenrod stem. Outside is hard, smooth, and pale yellow.

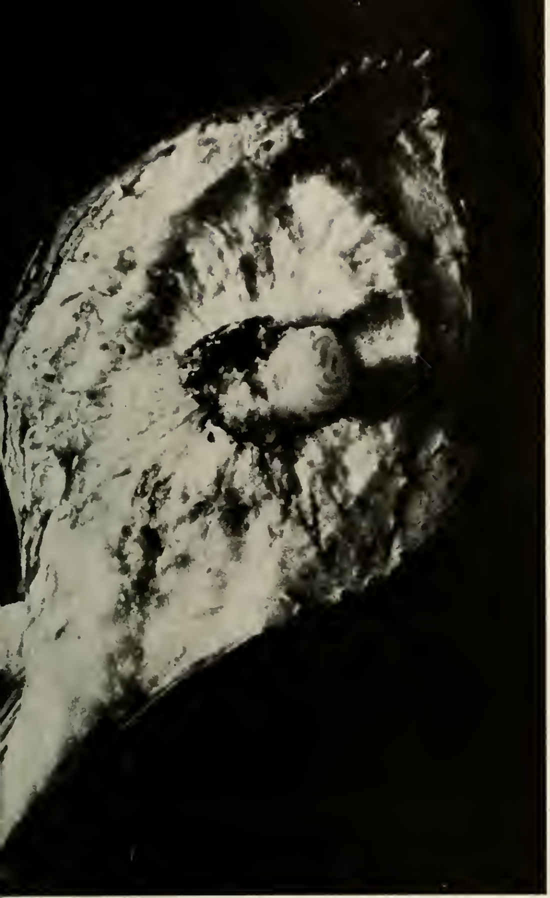
Tiny exit hole is visible in empty gall shell after its resident has departed.

than spheroidal. Thus, a given species of insect invariably produces a characteristic gall, and in some instances may be identified by the gall it causes.

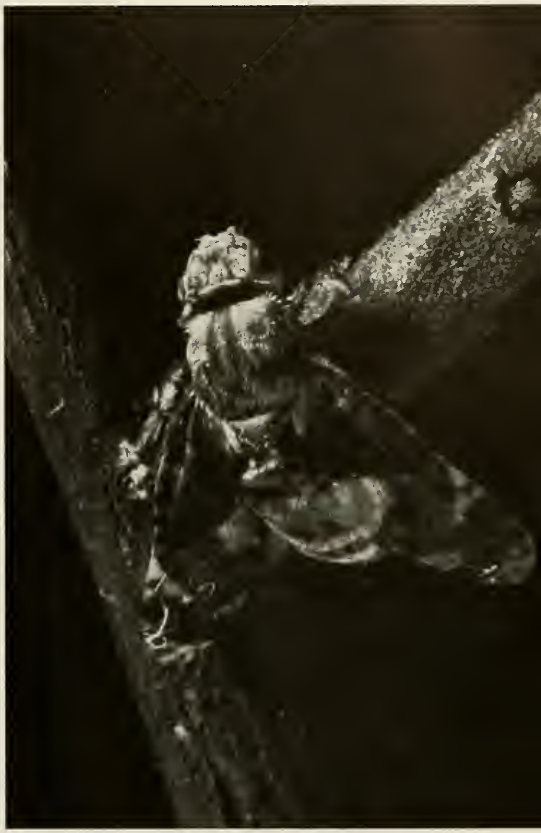
The larvae begin to mature in the autumn, but most do not reach full size until the following spring. Soon after it matures, the larva becomes an immobile pupa—a nonfeeding form, in which the insect passes the period of internal and external development during which it completes its transformation from wormlike larva into winged fly. While the fly develops, the skin of the pupa becomes a puparium, or saclike covering over the young adult.

In different parts of their range, the adult flies appear from mid-April to early June. At the time of emergence from the confines of its puparium, the fly inflates a large, balloon-like bladder that emerges through a slit in its head immediately above the antennae. This bladder, known as the ptilinum, covers the entire top of the head and extends laterally over both eyes like a pompadour. Its inflation forces off the top of the puparium and makes an opening large enough for the fly to escape. It then crawls through the tunnel that it excavated through the spongy part of the gall while still a larva. When it reaches the gall's hard outer surface, the fly rhythmically inflates and deflates its ptilinum in an effort to break through.

Several fascinating descriptions of the flies' exit have been written. In 1914, a student at Cornell University noted that, at first, a tiny section of the gall's hard shell was broken off by a push from the inside. This was fol-



brown. Inside is white and spongy. Near the center is small, irregular chamber where larva feeds and grows in summer.

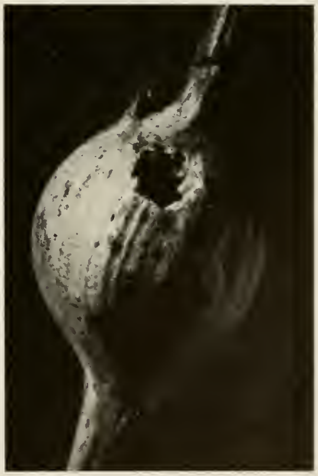


Liberated fly, free from gall after twenty-minute struggle, rests on twig as its body shapes, its wings expand and dry.

lowed immediately by the appearance of the fly's ptilinum, resembling a tiny drop of water. Suddenly the ptilinum withdrew into the gall and was almost lost to sight. Then, just as suddenly, it swelled out, elongated, and pushed through the minute hole. The fly struggled for a moment until its entire head emerged. The fly moved its head about, while the ptilinum continued to expand and contract.

The fly continued to struggle. Gradually, it squeezed the front of its thorax out of the gall. Almost every part of its upper body moved, dragged, squirmed, or shrugged until, after eighteen or nineteen minutes, the fly succeeded in pulling its entire thorax and all its legs through the hole. When its legs obtained a hold on the gall's shell, the fly's efforts seemed to increase. With a tremendous effort, it pulled its abdomen and wings free.

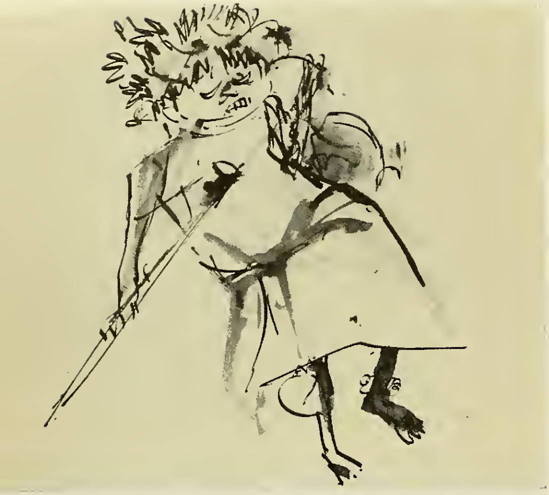
The exhausted fly was now liberated from the gall. Its abdomen was much compressed and elongated, and its unexpanded wings, moist and pliable, were crossed lengthwise. Sporadic movements of the abdomen indicated that the fly was breathing heavily. While the fly rested, its ptilinum began to shrink and then suddenly disappeared into the slit in the animal's head. After half an hour, the abdomen was rounded and plump, the wings were unfolded, expanded, and dried, and the fully formed gallfly stood bathed in the morning sunlight. Within a short time, it took wing. If its search for a mate proved successful, more gallfly eggs would be deposited within a few days and the cycle would begin anew.



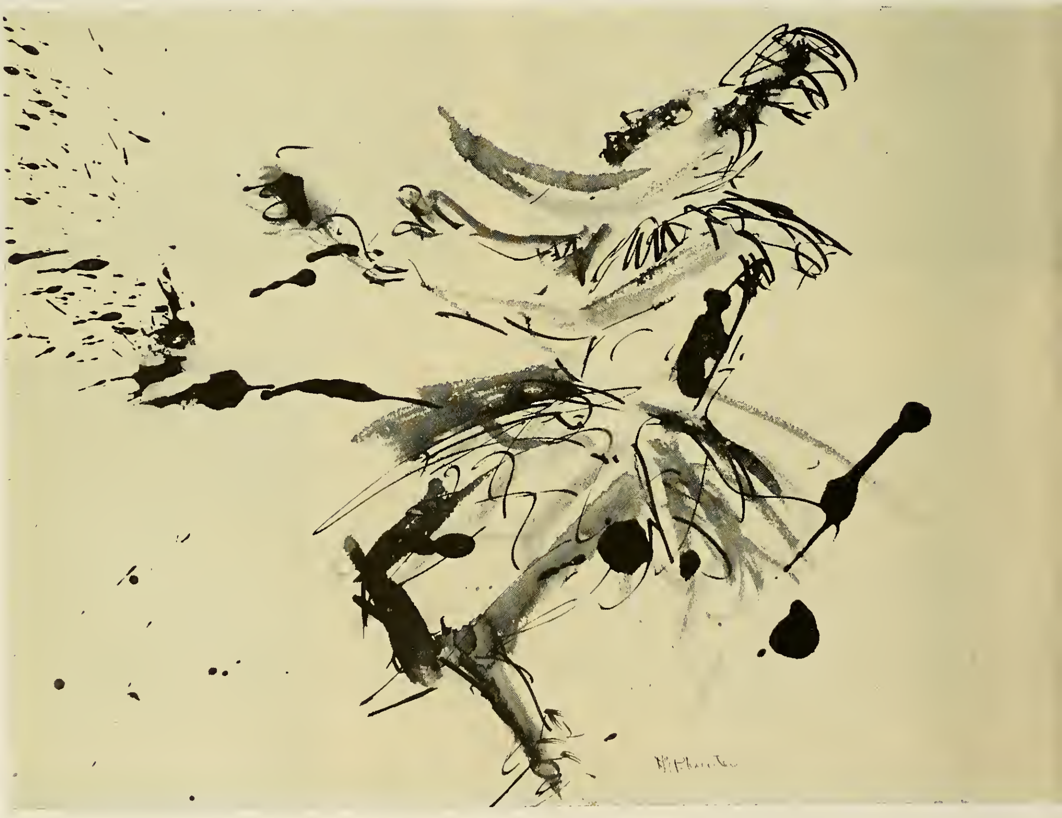
This ragged hole was made by rodent or woodpecker seeking an immature fly.

By Al and Lotte Blaustein

Visit To A Congo Jamboree



Pleasure is the aim of this jungle dance drama.

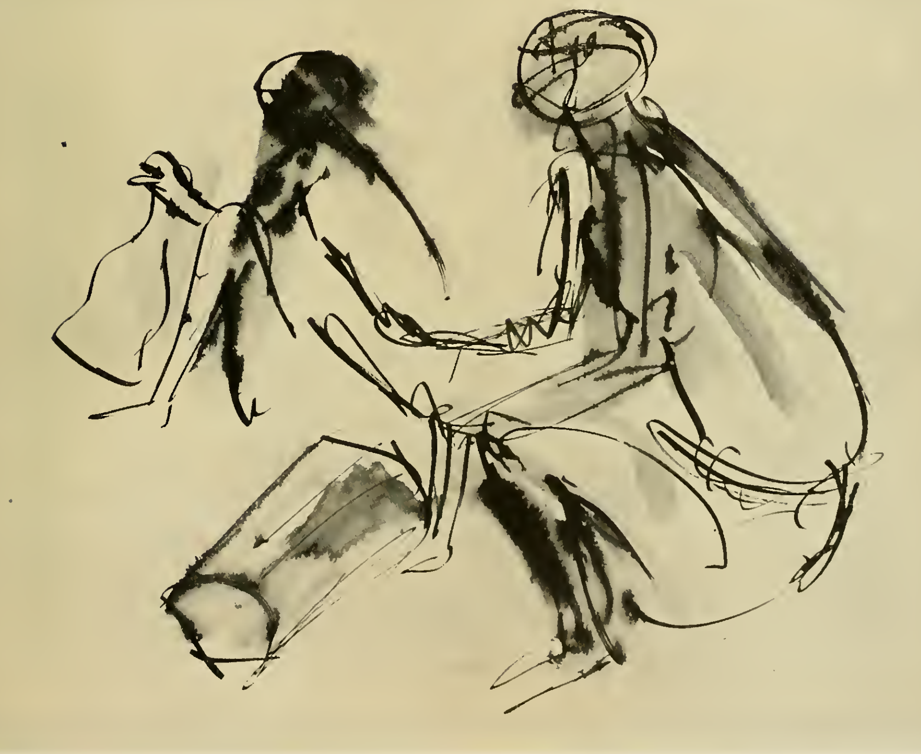


Many aborigines dance only ritually. The Bapende also dance for fun.

THE BAPENDE TRIBE of the Belgian Congo live in that eastern portion of the province of Leopoldville, which extends roughly from Kikwit, past Gungu and Kilembe, to the Loange River. Like other aboriginals, the Bapende use music and dance as essential corollaries to the important events in their tribal life—birth, death, the hunt, and celebrations of victory. Boys are initiated into manhood and guests are greeted with a *ngoma,* or dance.

But the Bapende differ in one marked respect from most of their fellows—they are among the few peoples of Central Africa who also dance sheerly for their own entertainment. They have, in fact, a traditional and varied dance theater, which consists of a series of improvised pantomimes, each with its set cast of from ten to thirty-two individual performers. The characters seldom vary—the Witch Doctor, *Ganga-Ngombo;* the Clown, *Tundu;* the figures symbolical of Prosperity and of Evil; and the dread *Migangi,* who guards the secret circumcision ceremonies against intrusion by women and children. Each character is instantly recognized by his audience. As in our own melodramas, the hero is applauded, the clown is cheered, the villain is hissed. And, as in much make-believe, the evil spirit inspires genuine terror among the young, even though they know that behind the frightening mask is, in truth, a familiar face.

THE performance takes place in the clearing that forms the center of most Bapende villages. Palm trees shade the dwellings from the broiling heat of day and act as backdrops for the dance drama. From behind bamboo fences, which protect homes and granaries from marauding animals, women and small children watch, listening impatiently for the drum that will signal the entrance of the first figure of the drama. A fire is built and smoke drifts up, curtaining the palm grove with a blue scrim. The drummers, wearing bright cotton skirts and raffia bracelets, pass their cylindrical drums slowly over the heat of the flames to tighten the skins to a desired pitch. Then, all the young boys of the tribe are herded into one spot under a tree, where they settle down to perform their function of chorus and vocal orchestra. As they become quiet, the chief, coated

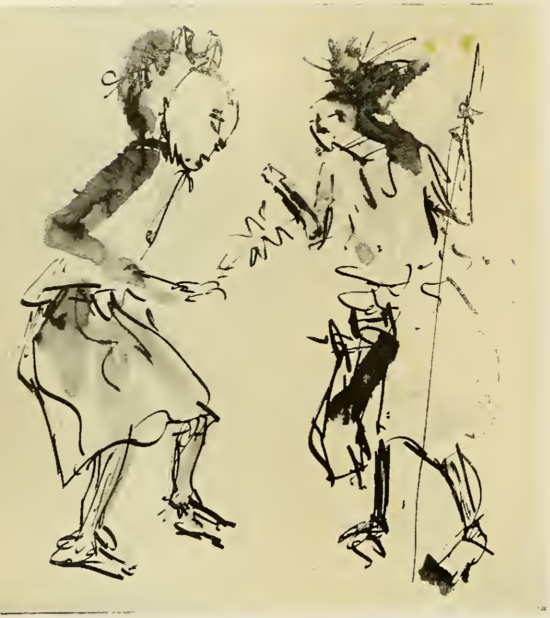


Drummers beat out accelerating tempo as "Muyembe," the human top, at left, spins wildly until he is exhausted.

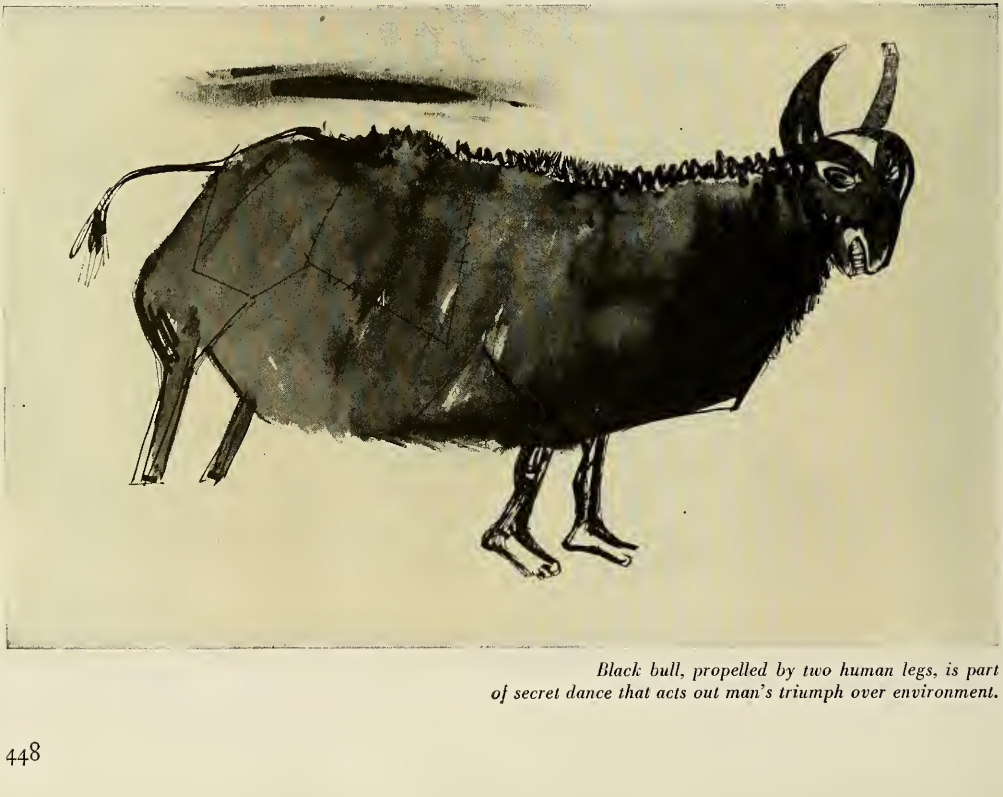
from loincloth to chin with red *ngula* clay, and wearing a horned headdress, arrives. Playing attendance to the chief are the village judge and the tribal elders.

Suddenly a shout goes up from some sharp-eyed children. Stragglers squeal and run to join the safety of the chorus. The shout can mean only that someone has spied *Migangi*, his huge, empty, eye sockets set in a round, wooden face, peering from a bush. Once he has been spotted, his frail, striped body, topped by the burden of the great platter face, emerges from the jungle. With a tail of feathers whipping in his wake, he turns, twists, wields a menacing stick, and makes straight for the children. The bravest of them stay huddled together on the ground, arms raised to ward off his blows. The less intrepid run into the dwellings, stumbling over their own thin legs in fright.

THE drums begin pounding, accompanied by a high falsetto recitation by the head drummer, and *Muyembe*, the human spinning top, whirls out into the sun. Everything about his costume suggests bristling motion: the multilayered skirt made of strips of animal skins, the fiber ruffle around his shoulders and chest, the red tassels on his upper arms. His small, vermilion mask has a bulky grass beard at one end, a fountain of feathers on the other, and is worn on top of his head like a huge hat. For the mask to be visible, therefore, *Muyembe* must dance with his head lowered and his chin almost touching his chest. He turns slowly at first. The head drummer approaches him from the orchestra, calling the dance movements. *Muyembe* picks up speed and moves in toward the drummer, arms



Nonritualistic "Mbuya" dancers dramatize facets of everyday life: good and evil, comedy and tragedy.



Black bull, propelled by two human legs, is part of secret dance that acts out man's triumph over environment.

flailing alternately close to the ground and above his head. The bushy dancing-whisks he holds in his hands act as propellers in his spins. As his momentum increases, so does the delight of his vociferous audience.

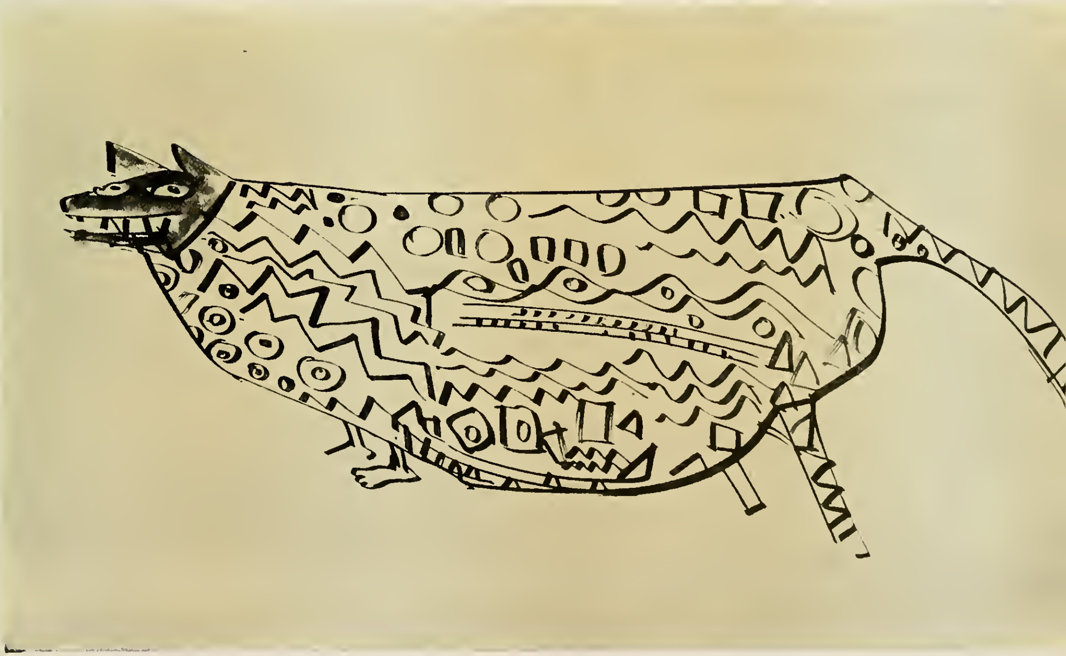
When the human top retires exhausted, the character known as the Cripple hobbles into the clearing. Staggering under the burden of a great sack, he braces himself on a stick. The cause of his disability is represented by a white bundle of cloth sewed onto one stiffly held leg. His drab, brownish costume is relieved by a flaming-orange wig and by white teeth set in a dead-black mask. The audience greets with howls of laughter his expert mimicry of limps, falls, and pathetic struggles to regain his feet. His physical plight is of small concern to these Congo people, who live with hardship all their days.

The umbrella is the mark of the next dancer's prestige. As Witch Doctor, *Ganga-Ngombo* is a much feared member of the tribe, with power even over the spirit world. He may bless and cure, or curse—and is therefore greeted with a show of approval. *Kambanda*, the Prostitute, wears the only white mask in the dance drama, possibly signifying that prostitution was introduced with the arrival of Europeans. The Clown teases both audience and dancers as he darts in and out among them, pulling skirts, slapping heads with his dancing-whisks, and waggling the four horns on his head.

The dance is at its peak. As each new dancer appears from behind the proscenium arch of foliage, he may be joined by one or another of the previous performers. Women's voices, from behind the fences of the dwellings, join in with those of the boys and men. As soon as a new mask is seen behind some bush, the word travels quickly through the crowd and everyone demands that the dancer make a solo appearance. The drama has no set ending: its duration depends on the stamina of the performers, the enthusiasm of the crowd, or the command of the chief.

While traveling through Central Africa, AL BLAUSTEIN, an artist, sketched the dancers of Bapende at first hand. His wife, LOTTE, provided this eyewitness account of the event.

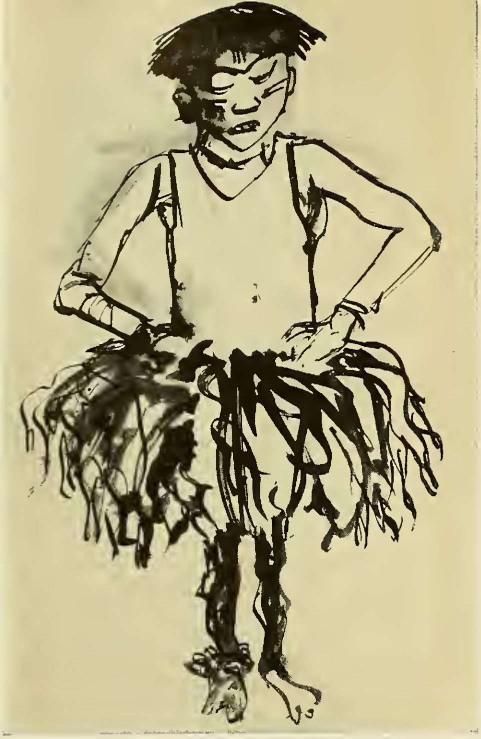
ON some special occasions an intermission is called, during which only the men and honored guests are allowed to witness a "secret" pageant in the palm forest. Single file, they wind their way through the high grass into the sun-flecked shadow of the woods. In a small clearing, dark, animal-like shapes stand crowded together. The eye gradually separates these individual allegorical figures from the surrounding gloom. There is a great black body, supported by two stick legs and two human ones, topped by a horned bull-mask that wags up and down. There is a wildly decorated, crocodile-like creature, its body, except for head and scrawny tail, completely covered with circles, zigzags, and fanciful geometric shapes. Crouching low, it scrapes its belly back and forth along the ground. There is a monstrous Royal Couple, mounted on a wooden platform, attended by a red-faced, masked figure that stands motionless. As King and Queen of the assembled group, they are elegantly dressed in brilliant cotton skirts and red *Mbuya* masks. The King's breastplate is a mirror. The



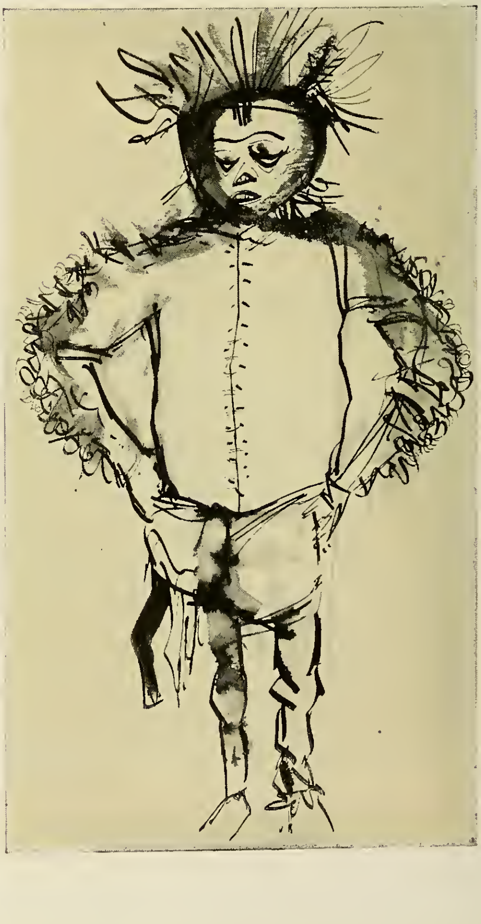
Crocodile is another fierce figure in secret drama. Object of the pantomime is to frighten or lure him away.

Queen is decorated with strings of beads across her burlap chest. At a signal from the village judge, all these figures move or are carried in procession toward the village. Several men are in charge of chasing away curious women and children. The small, privileged audience then gathers in a hot, grassy field near the village's edge.

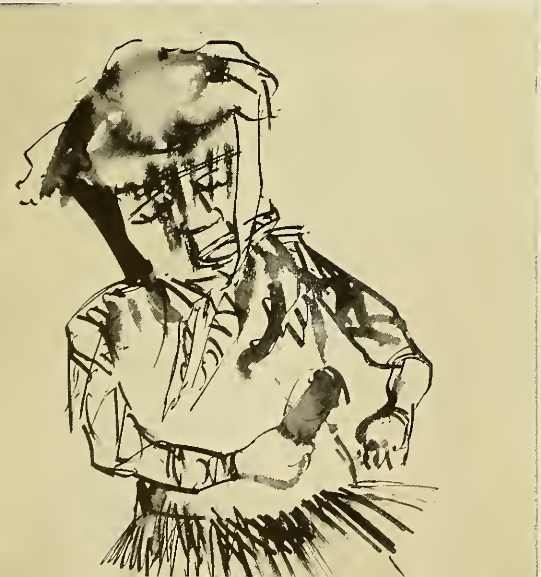
Soon the Royal Couple sways into view, carried on the shoulders of the singing elders. A form of court etiquette requires each spectator to salute the King who, in turn, slaps one arm against his hollow head in acknowledgment. Royalty is followed by the Bull. With much flexing of muscles and shaking of mud-clotted heads, two expert dancers persuade the beast to return to its hiding place. The Crocodile requires more appeasement. It advances on the viewers, snapping its jaws. One tribesman suspends an animal tail from a fishing rod and dangles it before the animal. Another tickles its painted back with a palm branch. Then, the powerful spell of the Belgian flag, flourished like a magic wand above the beast, is invoked, also to no avail. At last, a handful of grass, offered with a show of superhuman courage by one of the men, apparently satisfies the beast's hunger. As the Crocodile slinks peacefully away, the men return to the village with shouts of satisfaction, to tell of their victorious encounter with the secret creatures.



White mask, worn by man playing "Kambanda," the Prostitute, above, may reflect on European morals.



Man-Who-Told-a-Lie, right, wears twisted mask of shame, dances object lesson for boys in the tribe.



"Tundu," the Clown, below, performs in classic tradition by teasing both audience and other dancers.

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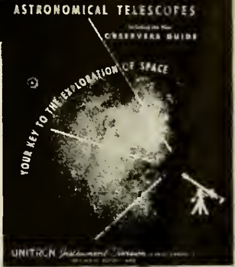
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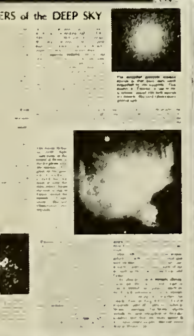
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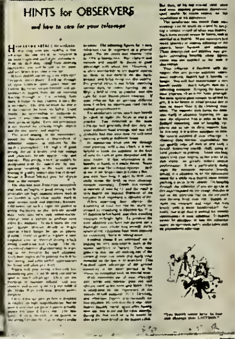
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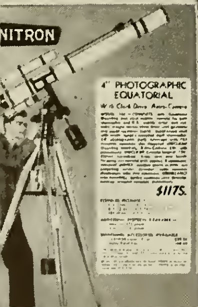
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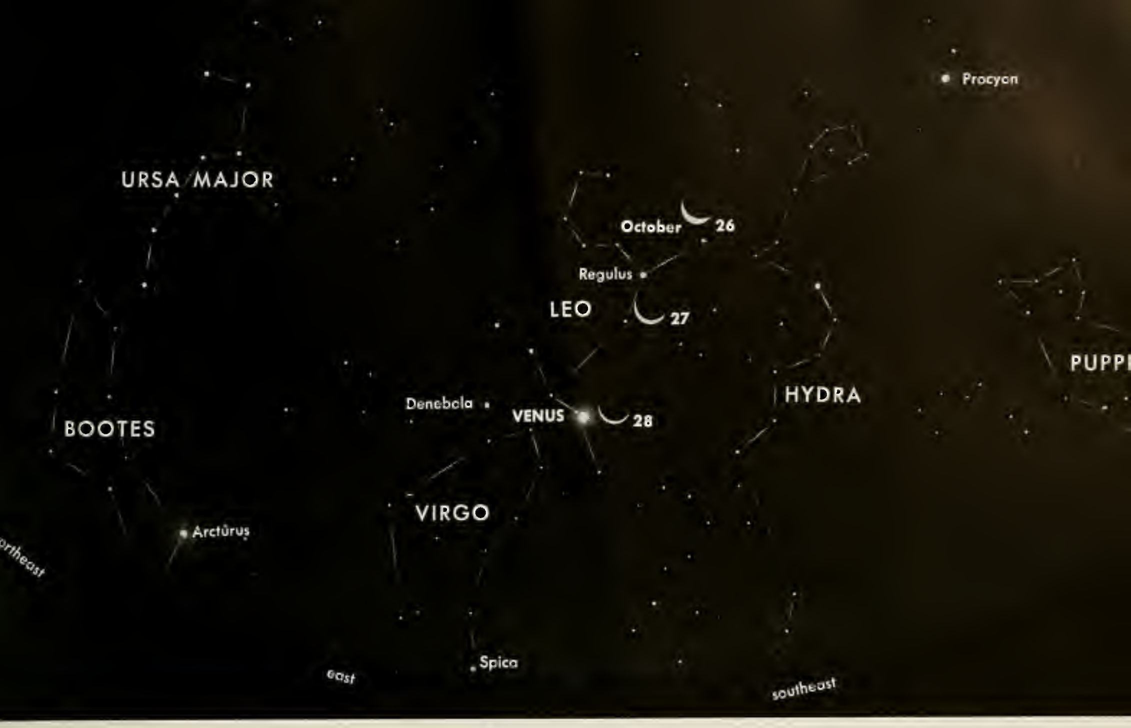


SKY REPORTER

By
Henry M. Neely

THE MOST IMPORTANT ASTRONOMICAL EVENT this month is, of course, the total eclipse of the sun on October 2 (see the article, beginning on page 430, for general information and advice to prospective viewers).

For observers who will not be able to see any phase of the eclipse, however, the October sky still brings many objects of interest. Of these, the planets will continue the effective display they have been making for many months, although two of them—Mercury and Mars—will be absent from our night skies this month.

Mercury circled to the far side of the sun (superior conjunction) on September 17 and it has still not swung far enough around to be free of the sun's glare.

Mars is also apparently close to the sun, and will be in line with it—as seen from the earth—on October 29.

But Jupiter and Saturn are still with us in the early evenings and Venus is a brilliant object in the sky, between east and southeast, as dawn begins.

Jupiter is not shown on this month's "roll-around" map, because it is just setting at the times for using the map. Incidentally, it should be noted that all times here are Standard Time, therefore, all readers who live in New York and other localities that continue Daylight Saving Time through October must remember to add an hour.

Although not on the map, Jupiter will be easily seen low over the southwest as full darkness comes on. This great planet and the three-day-old moon make an effective picture shortly after 6:00 P.M. on October 5—with Jupiter a little lower and somewhat to the left of the moon.

Saturn is on the map, over the southwest. It is brighter than any nearby star; the close approach of the moon, about 6:30 P.M. on October 7, will be worth seeing.

Most brilliant of all, however, will be Venus, which, on October 8, reaches almost its maximum possible brightness. The special map, *above*, shows its position at about 5:00 A.M. The dwindling wisp of the old moon on October 26, 27, and 28 will add to the beauty of the predawn sky.

This form of map is often called a "rocker." Just as the standard roll-around map is to be turned to bring the compass direction you are facing to the bottom, so this rocker map should be tilted a little to the right if facing southeast, or to the left if facing east. Objects can be located vertically upward from the horizon.

Venus is here seen among the stars that will dominate our sky in the evenings of spring and the fact that they can be seen before dawn in October emphasizes a statement often made in these articles—that the stars rise and set about four minutes earlier each succeeding day.

Four minutes a day means about two hours earlier each month. Thus, six months from now—say, April 27—these stars (but not Venus) will be in this same position twelve hours earlier, which means 5:00 P.M. instead of 5:00 A.M. But, in April, darkness does not come until about 8:00 P.M. and, by the time most people do their observing, these stars will be crossing the meridian.

Two famous star figures can be located with the moon's help on this month's map: the Teapot on October 7, and the Great Square of Pegasus, on October 13 and 14.

MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this regular feature for NATURAL HISTORY.

OCTOBER'S EVENTS of interest to sky watchers are arranged in calendar form, below:

OCTOBER 2: Total eclipse of the sun (*see page 430*).

OCTOBER 4: The moon reaches perigee—closest to the earth—at 4:00 P.M. Its distance will be 226,000 miles. For this month, it will be most distant—252,100 miles—on October 20, a difference for this month of 26,100 miles.

But perigee distances and apogee distances themselves show great fluctuations. This October perigee, for instance, is 3,200 miles closer than the perigee of last August, but the November perigee will be 4,400 miles closer than October's. In other words, the year's variation in perigee distances has a range of 7,600 miles. Oddly enough, the apogees show much less range. The December apogee will be 500 miles more distant than this month's. On the other hand, this month's apogee is 1,000 miles more distant than the one in August. The range between the year's most distant apogee (December) and closest perigee (November) is 31,000 miles and that distance varies from year to year.

OCTOBER 5: Jupiter and the young, crescent moon will present an attractive picture over the southwest horizon as full darkness comes on, about 6:30 P.M.

OCTOBER 7: Saturn and the five-day-old moon can be observed about 6:30 P.M., over the southwest. The moon will be about 3° higher than the planet and to its right.

OCTOBER 8: Venus reaches greatest brilliancy and will be a dazzling object, well up over the east, as dawn begins.

OCTOBER 9: The Giacobinids (meteors) are due. The moon will set before midnight, giving observers a chance to watch for these "shooting stars" while the radiant is still well up above the horizon over the northwest. These meteors seem to come from the "head" of Draco, seen at this time just to the right of brilliant Vega. An hour or so after midnight, the radiant will be too low for good seeing.

OCTOBER 16: Tonight's full moon is known in England as the Hunter's Moon because it brings three nights of practically full moonlight during the hunting season. Ordinarily, the moon rises about 50 minutes later each succeeding night but the September Harvest Moon and the October Hunter's Moon have the least "retardations" of the year. This month, the period will be only 32 minutes between October 13 and 14; 31 minutes between October 14 and 15; 32 minutes for 15—16 and 33 minutes for 16—17. These figures are for the mid-latitudes of the United States. For anyone at 70° N., the retardation would be only three or four minutes. After these dates, the retardation gradually increases and gets back to normal.

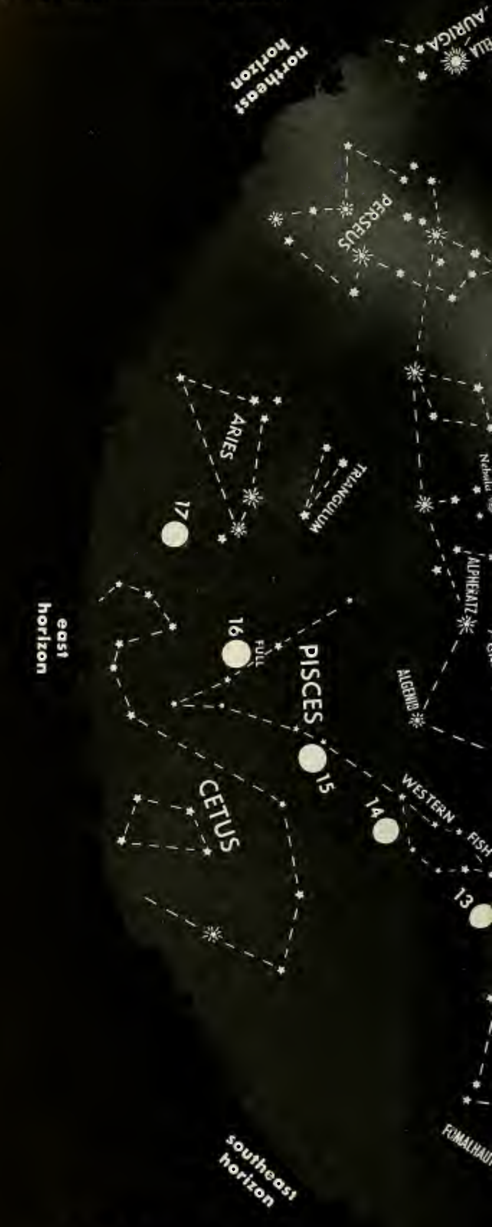
OCTOBER 20: This is the night for maximum of one of the best of the annual meteor showers—the Orionids—but the moon, midway between full and last quarter, will be so close to the radiant that the display will not be at its best. This shower lasts from October 16 to October 24 but the moon is full on October 16 and on October 21 and 22 it passes directly across the radiant.

OCTOBER 29: Mars is in "conjunction," which means that, on this date, the ruddy planet and the earth are in line on exactly opposite sides of the sun.

OCTOBER 31: The meteors known as the Taurids appear and may be looked for through most of next month.

THE MOON'S PHASES

New Moon	October 2
First Quarter	October 9
Full Moon	October 16
Last Quarter	October 24
New Moon	October 31

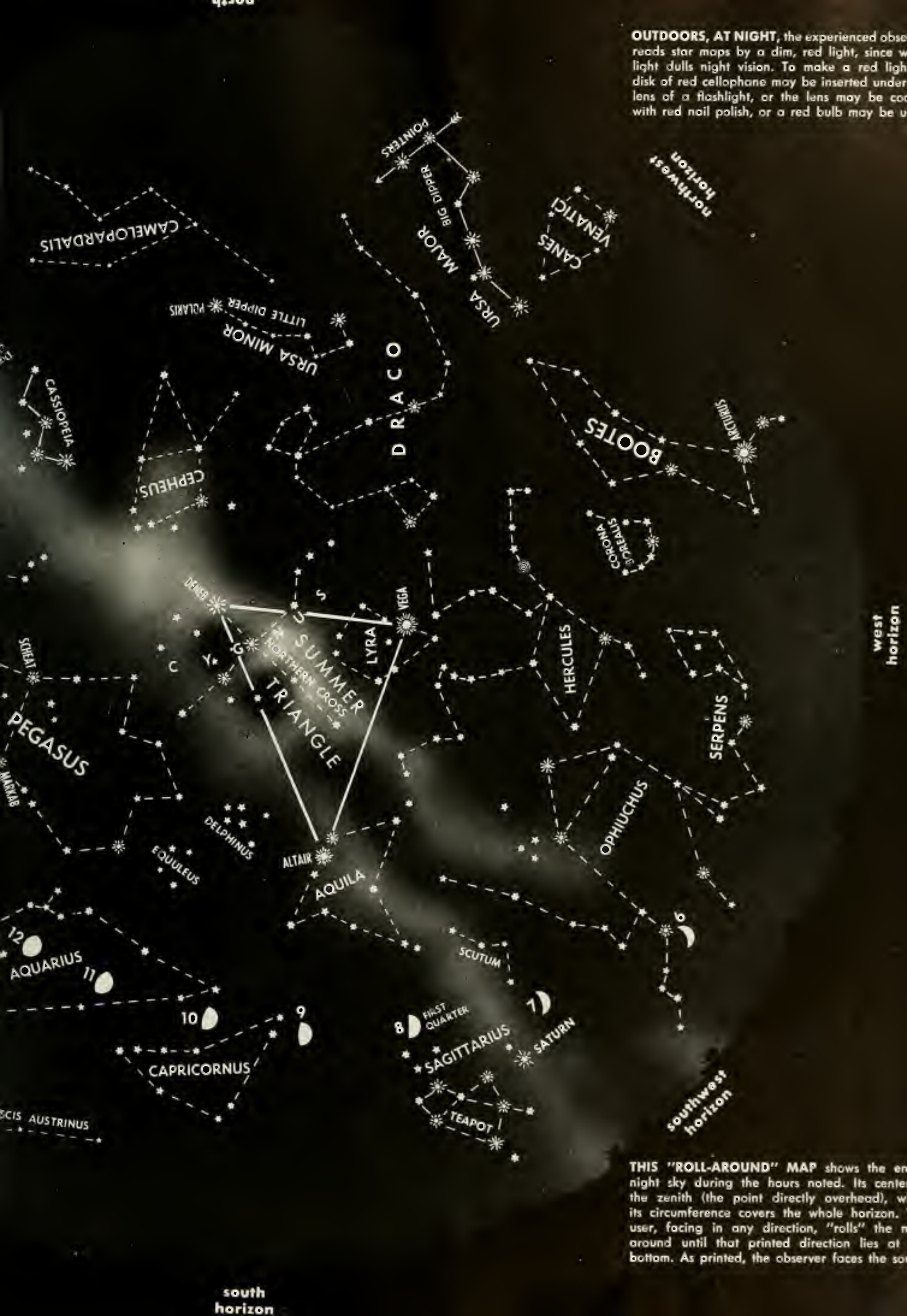


OCTOBER TIMETABLE

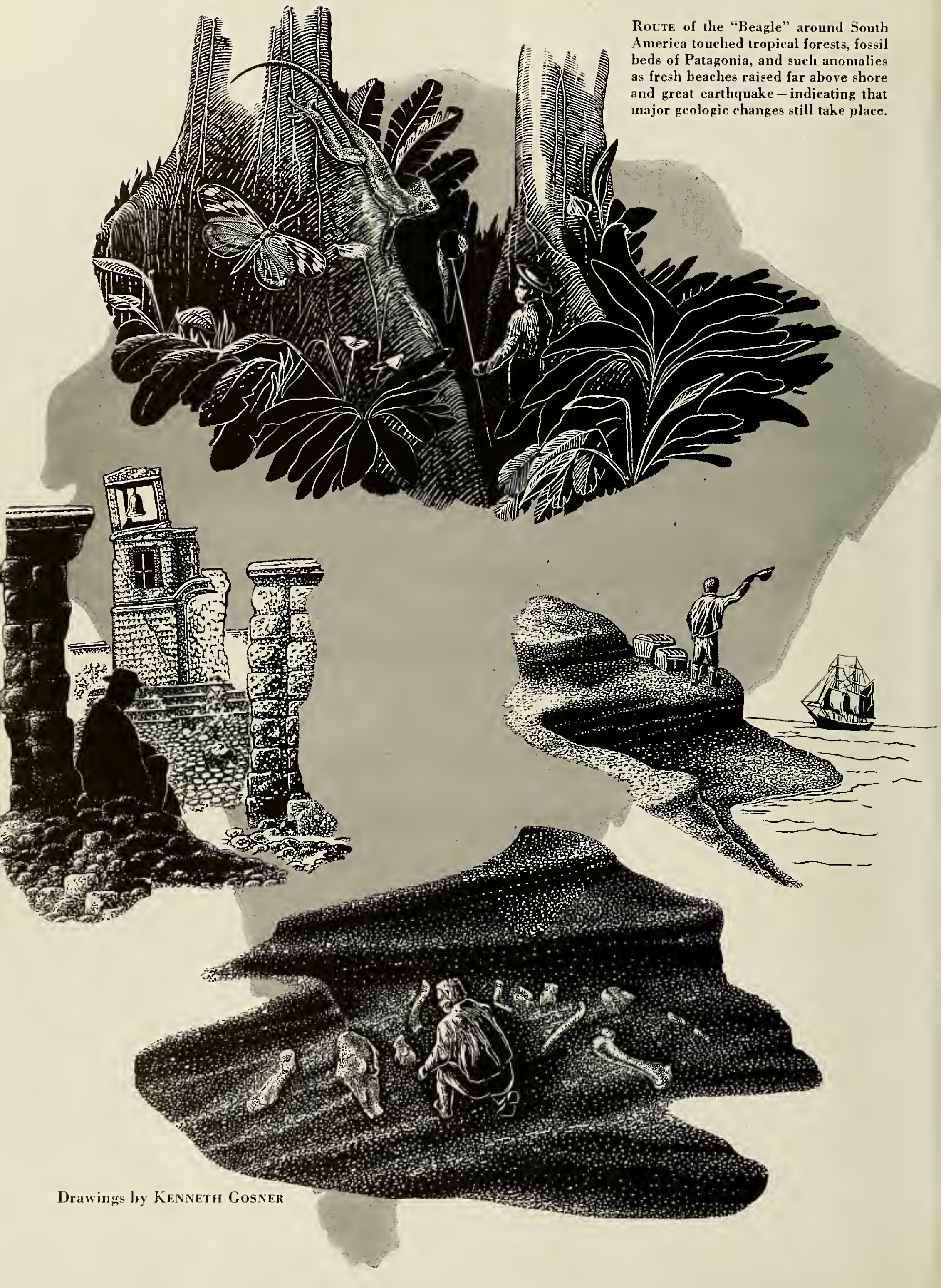
First week	7:20 to 8:20 P.M.
Second week	6:50 to 7:50 P.M.
Third week	6:20 to 7:20 P.M.
Last week	dark to 6:50 P.M.

(N.B., Standard Time)

OUTDOORS, AT NIGHT, the experienced observer reads star maps by a dim, red light, since white light dulls night vision. To make a red light, a disk of red cellophane may be inserted under the lens of a flashlight, or the lens may be coated with red nail polish, or a red bulb may be used.


north
northwest horizon
POINTERS
BIG DIPPER
URSA MAJOR
CANES VENATICI
CAMELOPARDALIS
LITTLE DIPPER
POLARIS
URSA MINOR
DRACO
CASSIOPEIA
CEPHEUS
BOOTES
ARCTURUS
CORONA BOREALIS
DENEB
CYGNUS
NORTHERN CROSS
SUMMER TRIANGLE
VEGA
LYRA
HERCULES
west horizon
SCHEAT
PEGASUS
MARKAB
SERPENS
OPHIUCHUS
DELPHINUS
EQUULEUS
ALTAIR
AQUILA
6
12
AQUARIUS
11
SCUTUM
10
9
8
FIRST QUARTER
7
SATURN
SAGITTARIUS
CAPRICORNUS
TEAPOT
southwest horizon
PISCIS AUSTRINUS
south horizon

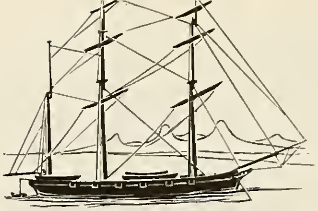
THIS "ROLL-AROUND" MAP shows the entire night sky during the hours noted. Its center is the zenith (the point directly overhead), while its circumference covers the whole horizon. The user, facing in any direction, "rolls" the map around until that printed direction lies at the bottom. As printed, the observer faces the south.



Route of the "Beagle" around South America touched tropical forests, fossil beds of Patagonia, and such anomalies as fresh beaches raised far above shore and great earthquake—indicating that major geologic changes still take place.

Drawings by Kenneth Gosner

DARWIN AND THE FOSSIL RECORD



In the century since Darwin's controversial theory first appeared, paleontologists have established a solid foundation for evolution

By Alfred S. Romer

"While on board H.M.S. "Beagle," as naturalist, I was much struck with certain facts in the distribution of the organic beings inhabiting South America, and in the geological relations of the present to the past inhabitants of that continent. These facts, as will be seen in the latter chapters of this volume, seemed to throw some light on the origin of species—that mystery of mysteries, as it has been called by one of our greatest philosophers." Thus, the opening sentences of Charles Darwin's immortal work, *The Origin of Species....* In part, it was his exposure to living animals and plants—of life in the tropical jungles, of the sharp contrast of the animal population of South America to that of his English homeland, of the curious character of island faunas—that turned Darwin's thoughts toward the problem of evolution.

But equally important in arousing Darwin's interest and stimulating his thought was the acquaintance he gained during the voyage with the geological past of South America—and the strange nature of its paleontological record, which he was among the first scientists to explore.

During his Edinburgh student days, Darwin had studied geology. At Cambridge, he undertook stratigraphic fieldwork in Shropshire and, with Sedgwick, in North Wales (Natural History, June–July, 1958). Under the essentially stable conditions of the mature topography of Great Britain, however, geological processes tended to be thought of as events of the past, which had little to do with the settled world as we find it today.

Far different was the picture presented along the coasts of Chile and Patagonia, where several years of this "Beagle" voyage were spent. The rise of the great chain of the Andes is, geologically, a relatively recent occurrence. Time after time, Darwin notes in his diary the presence of raised beaches—far above the present ocean level, but so fresh in appearance that the time since their formation can be estimated, at most, in thousands rather than millions of years. Here is a major geological event that is not, so to speak, dead and buried, but belongs to the present as much as to the past. That this active mountain-building is still going on was impressed on Darwin's mind by a major earthquake, which took place in southern Chile during the presence of the "Beagle" in 1934—one of the series of major earthquakes to which that region had been, and still is, subjected, and which is part of the process of Andean elevation. Obviously such revolutionary changes in the terrain must have a pronounced effect on the fauna and flora of the continent. Consideration of these effects leads inevitably to consideration of the possibility that evolutionary processes were involved in their coming to pass.

Today we are reasonably familiar with the general outlines of the faunal history of South America during the course of the Cenozoic Era. Almost at its beginning—some sixty to seventy million years ago, when the evolution of higher mammals was in its infancy—that continent was cut off from the rest of the world. It remained in isolation until probably not more than a million or so years ago, when connections with the northern continent were finally re-established by way of the Isthmus of Panama.

Relatively few kinds of mammals were present in South America at the time when communications were broken. During the long course of Tertiary times, when there evolved—in the northern continents—the majority of the mammal types familiar to us, there took place in the south a vast radiation of forms of a distinctive nature. Descendants of certain of these "natives" still survive. They include the opossums, primitive pouched mammals, little changed from their ancestor of Cretaceous times, at the end of the Mesozoic Era. Numerous and varied rodents are also found, belonging to a suborder quite distinct from those common on other continents. The monkeys of South America are of a type very different from those of the Old World tropics. And, most distinctive of all, South America is the home of armadillo, tree sloth, and anteater—sometimes grouped together in the order Edentata.

Even more striking were numerous other forms, now extinct but abounding in South America during mid-Tertiary times and often surviving into the Pleistocene, which is, geologically speaking, only yesterday. No carnivores of the kinds familiar in the Old World and North America had reached South America before the time of isolation, and—much as in Australia—pouched mammals, related to the opossum, developed into flesh-eaters, with forms comparable to the wolves and felids of northern continents. One such marsupial even developed parallel to the sabertooth "tigers" from the north.

Lacking, too, in South America's original fauna were any representatives of the orders to which the hoofed mammals of northern continents belong. A few primitive ungulates were present, however, and from them arose a spectacular array of hoofed forms, quite unlike those of any other region. *Toxodon*, for example, was a large and heavy beast, to some extent analogous to a hornless rhinoceros or a hippopotamus; *Macrauchenia* had the appearance of an ungainly camel; other forms had a superficial resemblance to horses and proboscidians; still others could be compared to nothing imaginable short of the creatures of nightmares. Adding to this grotesque array, the edentate order produced giant types in the glyptodonts—large relatives of the armadillo, the body covered by an arched carapace of bony armor — and numerous large and clumsy ground sloths, such as the giant creature *Megatherium.*

At the end of the Tertiary, connections with North America were re-established, and the downfall of South America's curious and isolated fauna began. A few southern forms ventured northward. Several sort of ground sloths and even glyptodonts invaded North America—to meet with temporary success but, in the end, to perish there as in their ancestral home, by the end of the Pleistocene glaciation. Of the adventurers to the north, only the North American porcupine, armadillo, and opossum (apparently a re-immigrant) have persisted.

Actually, movement along the isthmian land bridge between North and South America was mostly in the opposite direction—with catastrophic results for the native types. Progressive ungulates—llamas, deer, peccaries, and even proboscidians—entered from the north to compete with the primitive, native South American ungulates. Still more disastrous was the entry of advanced carnivores of the dog and cat tribes. These supplanted the carnivorous South American marsupials as predators, and obviously found the native herbivores an easy prey, although some of the latter lingered on through the Pleistocene. But, before modern times, all the more spectacular native mammals—the larger marsupials, the ground sloths, the glyptodonts, and every one of the numerous and varied ungulates—had vanished.

At the time the "Beagle" sailed, almost nothing was known of this story. A *Megatherium* skeleton had been found in the Argentine and sent to Madrid half a century before; mastodon teeth had been found by Von Humboldt and other travelers; several writers had mentioned the presence here and there of fossil bones, but had not described them. Nothing more. Darwin was thus one of the pioneers in studying the vertebrate paleontology of South America.

Unthinkingly, it might be assumed that Darwin's scientific work on the "Beagle" voyage was done *on* the ship. This would be, of course, almost exactly the reverse of the true situation. To be sure, he made some observations on marine life, and employed some time on the ship in working up his collections. But, as reference to his original diary will show, his principal occupation aboard was the "enjoyment" of seasickness. "I am now writing the memoranda of my misery for the last week. . . ." ". . . wretchedly out of spirits and very sick . . . ," and ". . . the misery is excessive . . . ," are characteristic entries. The "Beagle" was for Darwin essentially a means, although an uncomfortable one, of getting from one interesting region to another, and it was mainly on the occasions when he could leave the ship and spend some time ashore that his scientific work was really done.

Fortunately the nature of the "Beagle" mission — that of making coastal charts—made such opportunities of frequent occurrence, for the ship often tarried for considerable periods in a given region, sailing back and forth along the shores from port to port. The "Beagle" arrived at Montevideo in July, 1832; she passed the Straits of Magellan, bound for Chile, in June, 1834. Thus, nearly two years were spent off the coasts of Argentina and particularly Patagonia. Darwin had ample opportunity to explore the countryside. Fortunately for paleontology, although he was as much or more concerned with observation of living animals and plants, Darwin on a number of occasions came upon fossil-bearing beds.

In geological summary, the core of South America's Andes—and the regions adajcent to this mountain chain — are formed of igneous and metamorphic rocks and pre-Tertiary geological formations. Much of Patagonia, however, is composed of Tertiary beds that contain fossils in various areas. In northern Patagonia—and stretching as far to the north as Uruguay—lie the pampas, vast and nearly flat plains. These plains, as well as scattered areas farther south in Patagonia, are underlain by the so-called "Pampas Formation," relatively recent beds contemporary with the Pleistocene in the northern continents. Over these plains exposures are few, and mainly limited to bluffs along river channels and the coast, but the deposits, when they are found, are generally fossil-bearing.

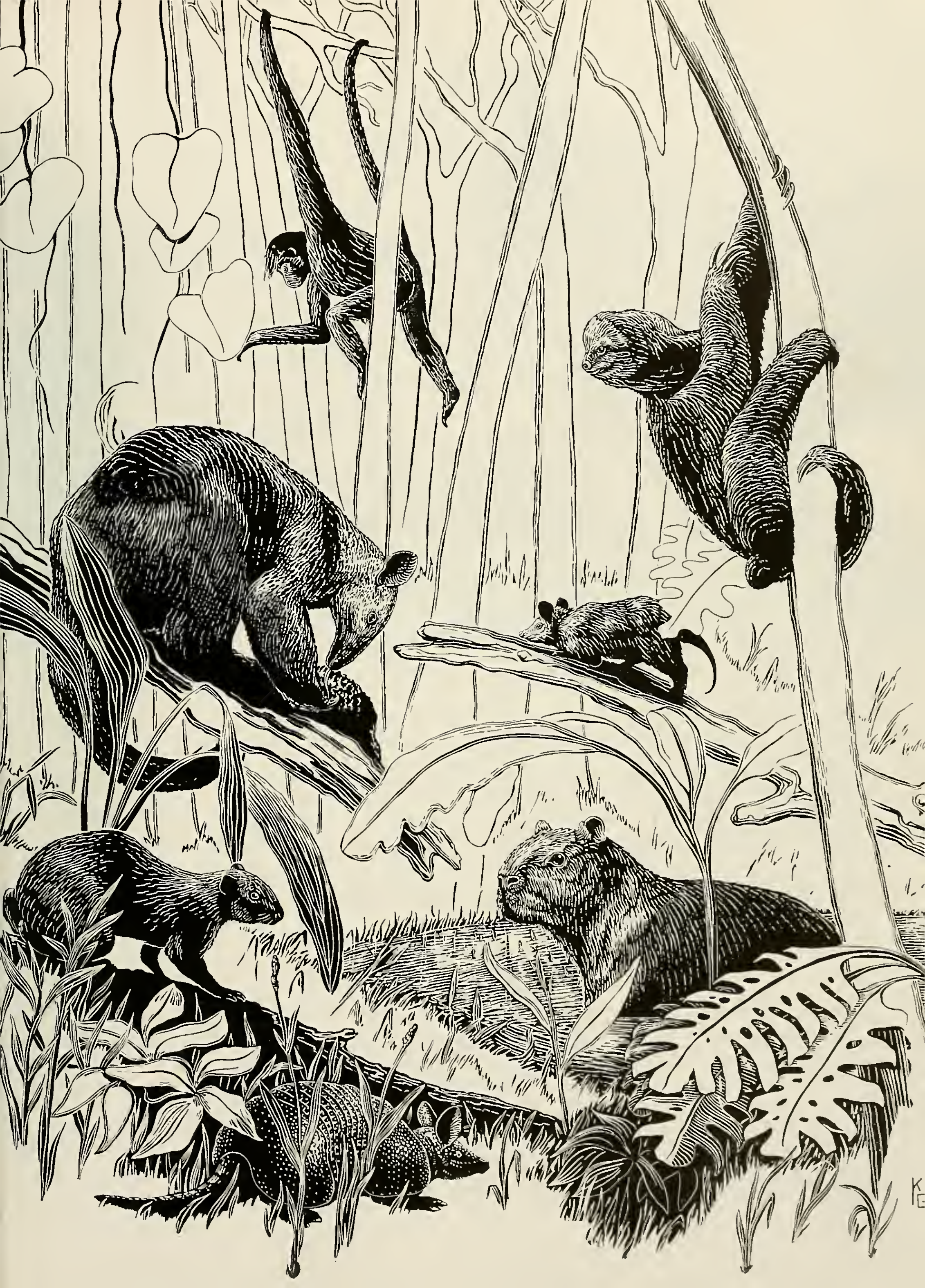
Darwin found fossils in the pampas beds on a number of occasions. Most of September and October of 1832 were spent by the "Beagle" in Bahía Blanca in northern Patagonia, and Darwin was ashore for much of the period. Here, let Darwin speak: "September 23 . . . I walked to Punta Alta to look after fossils; and to my great joy, I found the head of some large animal, imbedded in a soft rock. It took me nearly three hours to get it out. As far as I am able to judge, it is allied to the Rhinoceros." Darwin visited Punta Alta again on a number of occasions: this locality proved to be the most profitable one he discovered.

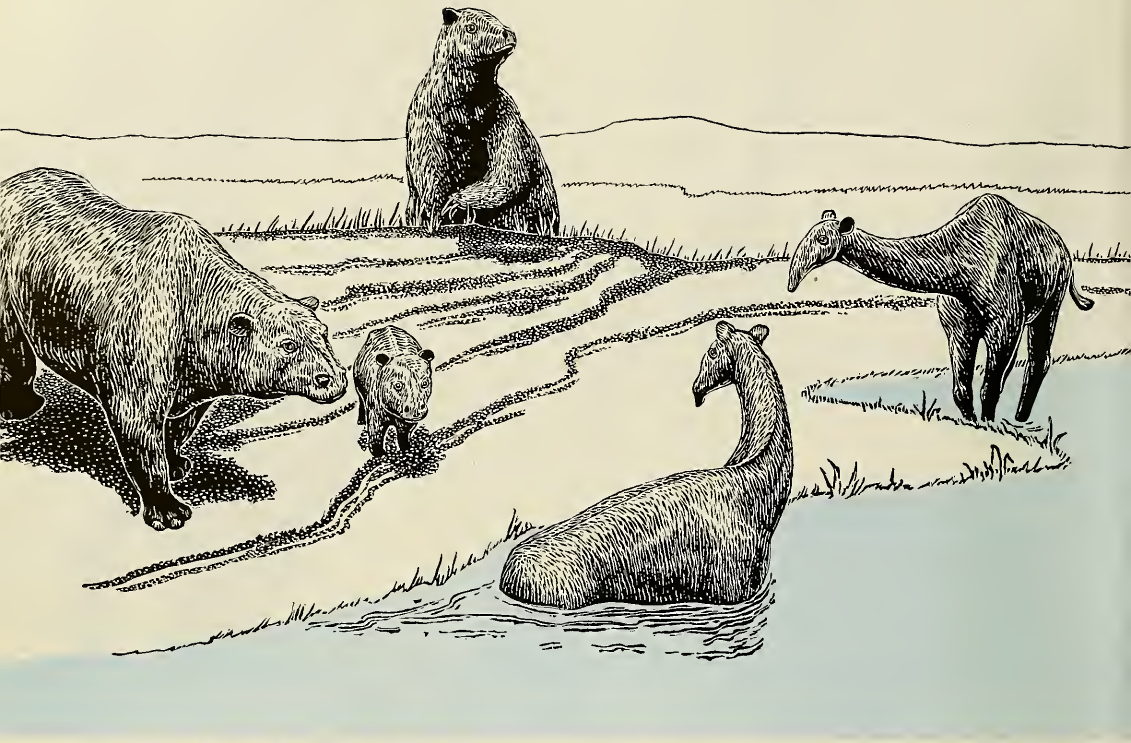
The animal he thought to be like a rhinoceros turned out, on later study, to be one of the large ground sloths (*Sceliodotherium*): much of its body skeleton, too, was unearthed at Punta Alta and—in addition to other giant sloth remains—a fossil horse tooth and a fragmentary lower jaw of *Toxodon;* the first discovery, I believe, of any member of the native ungulate groups.

Just before leaving Bahía Blanca, a brief stop was made at Monte Hermoso, farther up the bay, and some fossil rodent remains were found. The horizon here is a late Tertiary one, slightly older than the pampas beds from which all his other material was derived. The only other Patagonia locality from which Darwin recovered fossil vertebrates was at Port Saint Julien, far to the south, which was visited a year and a half later. Here, in an outlying patch of the Pampas Formation, he found a partial skeleton, lacking the skull, of *Macrauchenia*—a second, but very different, native ungulate.

Darwin was able to take several ex-

Modern South American Mammals seen in forest habitat first encountered by Darwin are drawn here. *Left,* from top to bottom, are the spider monkey, tamandua (tree anteater), agouti, and armadillo; *right,* three-toed tree sloth, opossum, and capybara. These animals, shown here in imaginary grouping, are distinctive South American types and developed during the continent's long isolation, which began in Cenozoic Era and lasted until a million years ago. Most unusual are tree sloth, tamandua, and armadillo, of the edentate order.





Extinct South American Mammals, all found by young Darwin in Patagonian fossil beds, were still more striking than modern relatives. *Left*, are mother and young Toxodon, primitive ungulate unique in South America; to their right,

tensive overland trips across the pampas—notably across the wild region from northern Patagonia to Buenos Aires; from that city upriver to Santa Fé and Paraná; and, in Uruguay, from Montevideo northwest to Mercedes on the Rio Negro, near the Rio Uruguay. On each of these journeys, some fossil material was obtained, despite the paucity of exposures: some glyptodont armor was discovered south of Buenos Aires; the cliffs of the Paraná yielded further glyptodont armor, another horse tooth and one *Toxodon*, and some poor remains of a mastodon.

Still other fossils were gathered from the Rio Negro region of Uruguay, including mastodon, sloth, and glyptodont specimens. Most notable was a skull of *Toxodon*, from the Sarandis River. This, although far from complete, was justifiably described in detail by Owen as the first-known cranial material of its order.

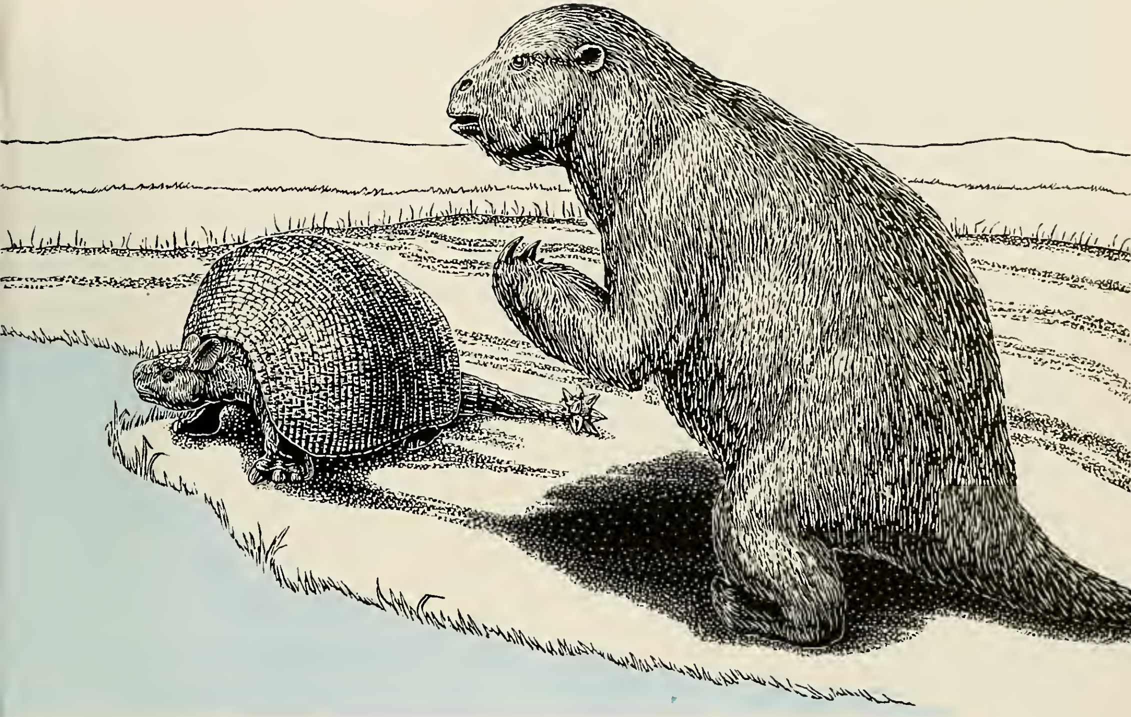
Darwin's note about this specimen illustrates the vicissitudes to which such a fossil may be subject: "The head had been kept for a short time in a neighbouring farm house as a curiosity," he wrote, "but when I arrived it was lying in the yard. I bought it for the value of eighteen-pence. The people informed me that when first discovered, about two years previously, it was quite perfect, but that the boys had since knocked out the teeth and had put it on a post as a mark to throw stones at."

It is amusing to reflect that Owen's work on Darwin's fossils, and the light they shed on the extinct fauna of South America, appears to have been one of the two main sources from which Darwin, once a firm believer in special creation, derived his final belief in evolution. In his diary for 1837, Darwin writes: "In July opened first notebook on 'Transmutation of Species.' Had been greatly struck from about month of previous March on character of S. American fossil—and species on Galapagos Archipelago. These facts origin (especially latter) of all my views."

Today, in any elementary book devoted to the topic of evolution, a substantial section is usually devoted to proofs of the reality of the evolutionary process, derived from a consideration of the fossil record, particularly that of the vertebrates. Not so in Darwin's classic. The treatment of the subject is essentially a negative one. For the most part, Darwin's argument is not that paleontology supports the evolutionary theory but, rather, that it need not be regarded as opposing it.

To understand this approach, it is necessary to recall the history of paleontological work. Today, evolution and paleontology march hand-in-hand. Paleontology supports evolution; the truth of evolution is a basic assumption underlying all paleontological work. This, however, was not the case in earlier days.

The paleontologists of Darwin's day not only lacked interest in



two Macrauchenia, another ungulate. Behind them is a giant ground sloth of the edentate order. Mylodon, another ground sloth, is seen at far right and, beside it, another variety of edentate, Glyptodon, a relative of the modern armadillo.

evolutionary ideas, but were inclined to view them with suspicion as detrimental to their work. For clear-cut stratigraphic work, the species in a given formation should be stable entities, clearly distinguishable from those in the strata above and below. The idea of gradual change and of transitional forms was abhorrent. With this to contend with, it is apparent why Darwin was thrown on the defensive in his treatment of the fossil record. Far from calling on the paleontologists for support, the most he could do was to show that it was at least *possible* to interpret the geological story in evolutionary terms, and that there were no insuperable objections.

PALEONTOLOGICAL data are cited in a variety of places in the *Origin*—for example, in the chapters on geographical distribution. Darwin's general argument on the fossil story is, however, concentrated in two chapters: "On the interpretation of the geological record" and "On the geological succession of organic beings." Of these two chapters the first is by far the more important. In it he discusses some of the arguments which might be—and were—brought against an evolutionary interpretation of the geological record, and answers most of them in a convincing fashion.

THE major objections, some of which continued (although with diminishing force) to be brought against evolutionary beliefs long after the time of the first publication of Darwin's work, may be stated as follows:

First, if the evolutionary theory were true, we should expect to find many fossil species or varieties of intermediate nature — "missing links," that is, in popular terminology. This, said opponents, was not the case.

Second, the extent of geological time is too brief for major evolutionary changes to have occurred.

Third, known fossils from the various periods and formations do not show a well-arranged phyletic pattern —as would be expected on evolutionary grounds—but a scattered, seemingly random, distribution of forms.

Fourth, if the history of life has been a gradual, evolutionary progression, we would expect to find gradual changes between forms in the lower and upper parts of geological formations. This is not the case.

Fifth, whole groups of species appear suddenly, in an abrupt manner, in certain formations, contrary to what one would expect if evolutionary development had occurred.

Sixth, a related and more serious problem is the sudden appearance, without known antecedents, in the lowest-known, fossiliferous strata—the Cambrian—of a whole series of animals that belong to a variety of major animal types.

DARWIN discusses these objections *seriatim* and is able, for the most part, to give convincing answers. As to the absence of intermediate varieties, the "missing links," in an earlier section of the *Origin*. he had given quite satisfactory reasons for the rarity, at the present day, of types intermediate between living forms. The same situation should hold for any given geological formation. Further, he points out, if one is looking in the fossil record for "intermediates," what should they be intermediate between? For example, says Darwin, should we look—today or in any older formation—for an intermediate between a horse and a tapir—a form which "splits the difference" between the two? It is, he says, highly improbable that either has descended from the other. Rather, the two have presumably descended from a remote common ancestor; and we would be unable to recognize this remote ancestor—the *true* intermediate—without knowledge of the lines of descent of horse and tapir from it.

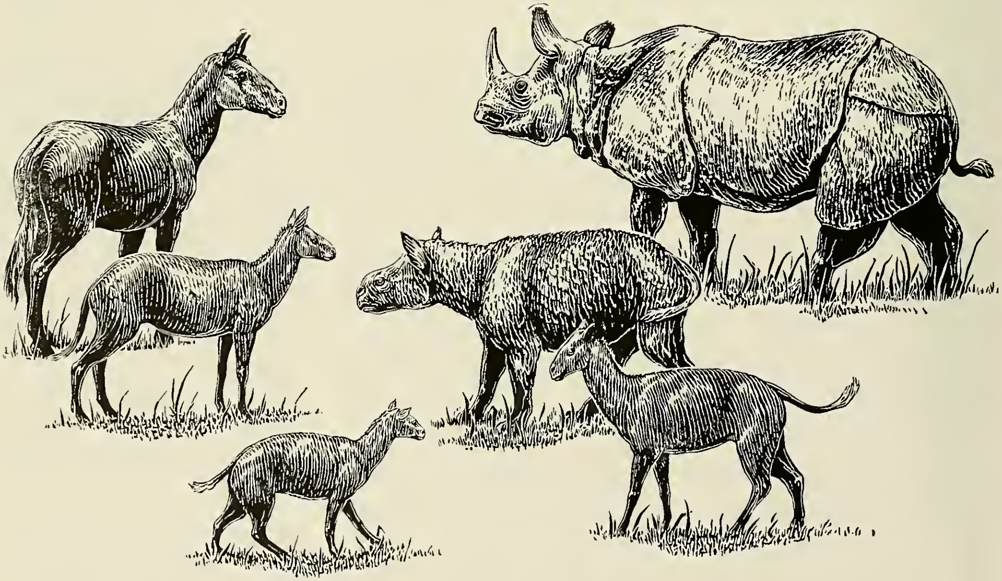
DARWIN could not have hit upon a happier illustration. Owen had recently described the skull of a small browsing animal from the English Eocene—which he named *Hyracotherium* because of the resemblance of its teeth to those of the living conies, or hyraxes, of Africa and Syria. Considerably later, with the discovery—in the American West—of linking types, it became apparent that *Hyracotherium* was an ancestral equid, and in recent decades it has been demonstrated that *Hyracotherium* and the widely known *Eohippus*, the "dawn horse," are generically identical. But *Hyracotherium* is not merely a direct horse ancestor; it is at least very close to the ancestor of the tapirs and other odd-toed ungulates. It is thus one of the "intermediates," the supposed absence of which was argued as an objection to evolution. But, just as Darwin pointed out would be the case, its nature was not recognized until further connecting links were discovered.

SECOND is the question whether geological time is insufficient. Our Christian ancestors were in general habituated to a chronology of the type promulgated by the learned Bishop Ussher, according to whose computations—from Old Testament data—the world was rather under 6,000 years of age. Even those who were willing to grant that the Biblical seven days of creation need not be taken literally still tended to regard the lapse of time since the earth began as a relatively short period.

Darwin presents the concept of a longer span of geological time most persuasively. He cites an estimate of the thickness of sediments, laid down since the beginning of the Paleozoic in one area or another of England, as having a total thickness of over 72,000 feet—nearly fourteen miles of accumulation. A vast amount of time was surely needed to form these deposits; and since there are many gaps in the English sequence, further major additions must be added to give the total time since the fossil sequence became established in Cambrian days at the opening of the Paleozoic Era.

How long in terms of years have the various eras and periods covered? In his first edition, Darwin estimates that the minimum time needed during the Tertiary to remove once overlying sediments—about 1,100 feet of them—from the Weald of Southern England must have been over three hundred million years, and that—since the process of denudation was presumably intermittent — the actual elapsed time would have been far longer.

DARWIN'S figure here, it would seem, is very far above any acceptable to his contemporaries. In later editions



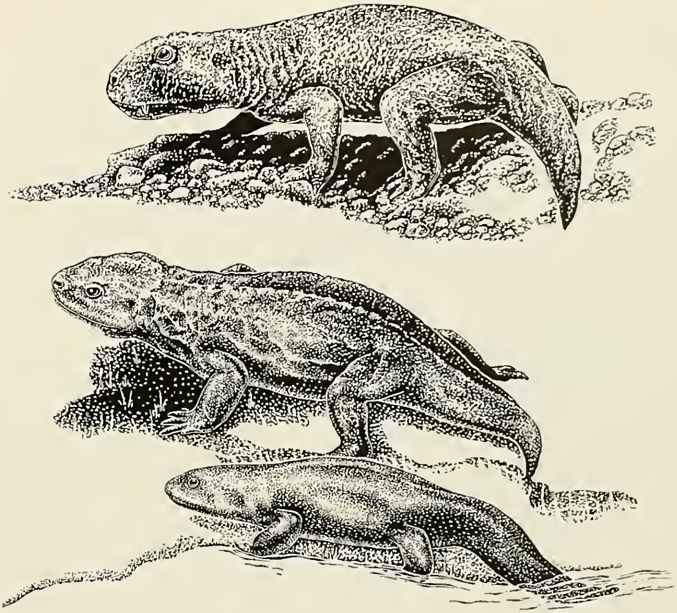
ROLE OF "MISSING LINKS" in evolution is shown here for two ungulates, the horse and rhinoceros, which had a dissimilar development from similar ancestors. Darwin's critics had said fossils were lacking that might link divergent forms.

of his work, this calculation is omitted, and the only estimate of any sort for which figures in years are given is one cited from Croll—to the effect that a thousand feet of sediments might be removed in about six million years. On this basis (although Darwin does not say this) the estimate for the Wealden degradation during the Tertiary might have been rather less than seven million years. This is on an order of magnitude that was more palatable, it would seem, to the geologists of the last century. Darwin even offers a further sop to the hesitant conservative by saying of the Croll estimate that "some considerations lead to the suspicion that it may be too large," and that it might be halved or quartered.

Up to the early decades of the present century, figures on the order of magnitude of the Croll calculations were those generally accepted. The time from the beginning of the Tertiary was frequently cited as about five million years, and from the beginning of the Paleozoic as about fifty million. Such figures were based on estimates of the minimum time needed to lay down the known series of sediments. It was agreed that, in all probability, some increase (although perhaps a modest one) might be needed to account for gaps that were observed in the sedimentary record.

During the past twenty-five years, there has been a massive upward revision of such figures due to study of radioactive rocks present at a number of levels in the geological column. The new figures have increased over the old by a factor of ten; the Tertiary is now commonly cited as having a duration of fifty to seventy million years, and the time elapsed since the beginning of the Paleozoic calculated to be five hundred million years or so. This is indeed a sharp jump but, even so, it falls far short of Darwin's original estimates. But whatever estimate one then accepted, or accepts now—the "short count," current figures, or Darwin's original long one—the span of geological time is certainly adequate for a very considerable amount of evolutionary change to have occurred within it.

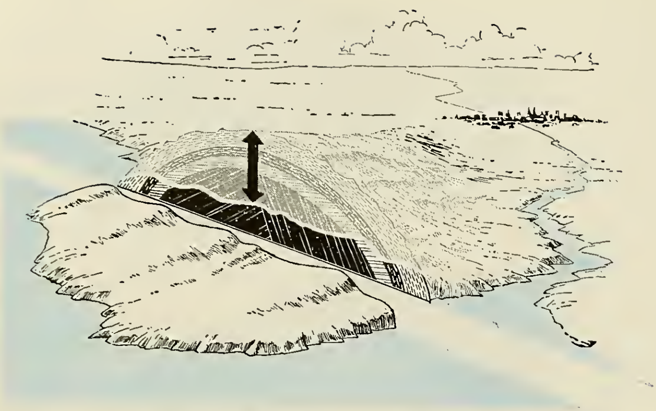
Third, there is the assertion that known fossils do not form a phyletic pattern, as would be expected on an evolutionary hypothesis. At the time of the first publication of the *Origin*—and, to a somewhat lesser degree, at the time of publication of later editions—this objection was one of seemingly great validity. The known record of past life was a very "spotty" one; to some extent the later formations in the sedimentary sequence showed the presence of "higher" forms of life, but this sequence could be explained on the basis of separate, successive creations—with "improved" forms being brought forth *de novo* in the later ones.



Patterns of phyla, little known in Darwin's time, also support his views. Shown is the evolution from amphibian Ichthyostega, *at bottom*, via Seymouria—a half-amphibian half-reptile—to the mammal-like reptile Lycaenops, *at top*.

Beyond this single general trend, there was no evidence of any phylogenetic "family tree." Even among the vertebrates, in which hard internal skeletal parts favor preservation as fossils, there was little indication at the time of any evolutionary arrangement of the animals then known. A fair assortment of fossil fishes had been described but, as Agassiz observed (even as late as in a posthumous paper in the 1870's), forms of a presumed advanced type had been found in older strata than those containing any fishes of a supposedly more primitive nature—the reverse of an evolutionary sequence. Intermediates between fishes and land vertebrates were practically unknown. Plesiosaurs and ichthyosaurs, the only reptiles than adequately described, were isolated — if spectacular — types that shed no light on the possible evolution of reptiles. Nothing was known to connect either birds or mammals with lower groups.

Why this seeming contradiction between the known fossil record and that expected on the evolutionary hypothesis? Darwin attributes it to the poorness of paleontological collections in his day. Only a small portion of the earth had then been geologically explored, and no part had been explored thoroughly. Of the fossil species then described, very many were known and named from single (and often broken or fragmentary) specimens, rendering interpretation difficult. In addition to the inadequacies of our knowledge of fossils due to insufficient exploration, there were other gaps due to imperfections of the geological record. Unless deposited in an area where sediments are being laid down, shells and bones decay quickly. It seems clear that, at any past time (as is true today), sedi-



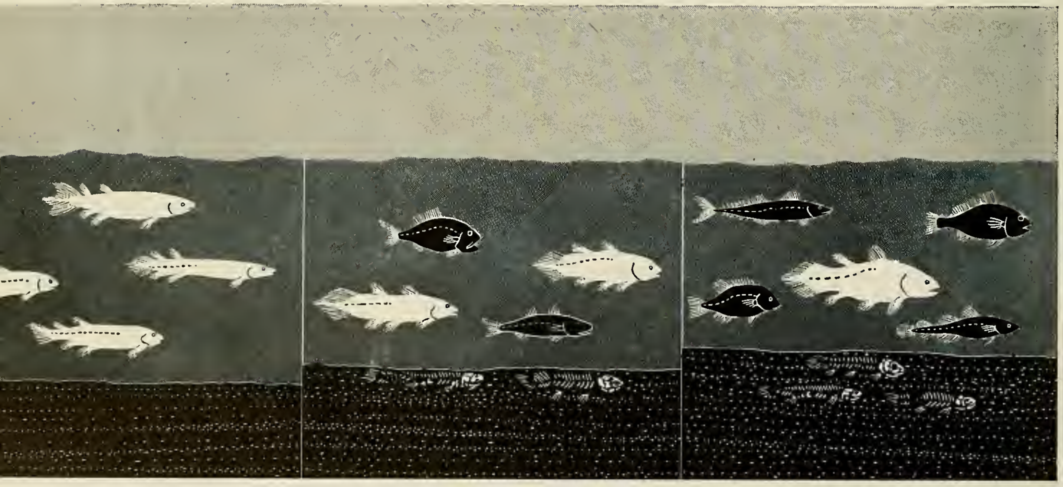
Thickness of sediment above Weald in southern England was used by Darwin to answer critics' charge that time did not allow for slowness of evolution. He first estimated interval since the start of the Tertiary as over 300 million years.

mentation was taking place over only a very small portion of the earth's surface, leaving great gaps in the preserved record of life in any given area. Further, the fact that an animal was fossilized is no guarantee that it would be preserved down to modern times—for degradation, of necessity, goes hand-in-hand with sedimentation.

Our knowledge of terrestrial formations in the earlier geological periods, Darwin points out, is hence extremely meager. There are vast areas of the earth (the Canadian Shield, for example) in which no unaltered sediments at all are present today: "primordial" rocks form the surface. In consequence, we shall never obtain a record of any former inhabitant of the region. And—discouragingly—many of the connecting links between major animal phyla, according to the evolutionary hypothesis, would have been soft-bodied animals. Although Darwin's statement that "no organism wholly soft can be preserved as a fossil" is too extreme, identifiable remains of such forms have, indeed, proven to be all too rare.

Many of the reasons advanced by Darwin for the imperfections of the fossil record are just as valid today as they were a century ago. It is certain that we shall never be able to find and describe more than a very small fraction of the former inhabitants of the earth. But wider exploration and further exploitation of fossiliferous deposits already known have added vastly, over the intervening decades, to the number and variety of known forms. And it is of major importance that, although no "family tree," even that of the vertebrates, is fully documented, nearly every new discovery fits into once hypothetical phylogenies. There are still, among the vertebrates, areas in which there are major lacunae—for example, the evolution of the earliest fishes, the origin of the modern amphibian orders and of certain reptile groups—but, in many portions of the "tree," the phyletic pattern is becoming increasingly clear.

Beyond the Middle Devonian, the general pattern of fish evolution is demonstrable. The gap between fishes and land vertebrates is gradually closing, through such discoveries as that of the Late Devonian amphibians of Greenland. Connections between early amphibians and the reptiles are so well documented that—in the case of such an animal as *Seymouria*, of the early Texas Permian—it is difficult to reach a firm



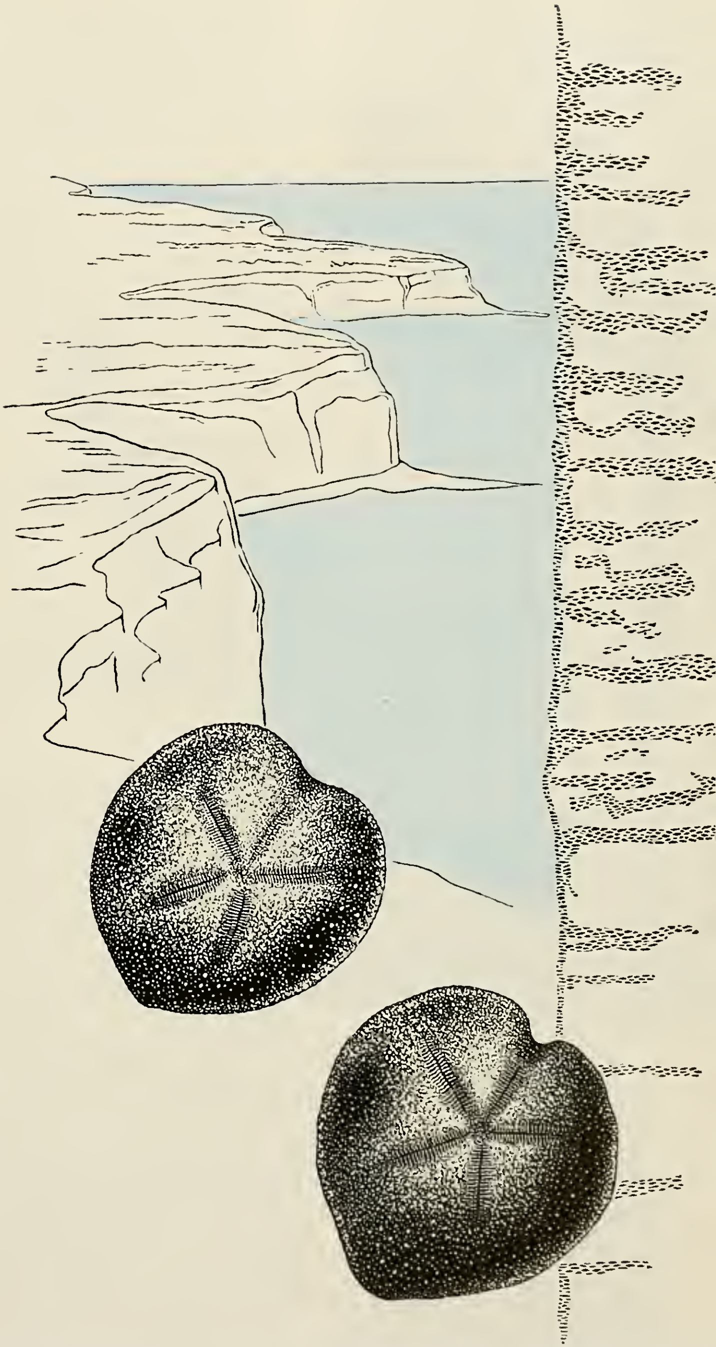
Gradual appearance of species was propounded by Darwin against opponents, who said process was abrupt. Example here is the coelacanth (solid forms), dominant in Paleozoic, *left*, and once thought to have died out in Mesozoic, *center*, but of which a few have lately been found alive. Inversely, the teleost fishes (outlined forms) have gradually emerged.

decision concerning the precise class to which it should be assigned.

Only a few years after the publication of Darwin's first edition there came the discovery of Archaeopteryx, filling a halfway position on the branch of the vertebrate tree leading from reptiles to advanced birds. Discoveries, first in South Africa and later in other regions, have closed much of the gap between reptiles and mammals. It is still necessary, today, to call attention to the obvious imperfections of the paleontological record, but the need is much less than in the last century and the approach to the fossil story can be a positive rather than the negative one that was once followed.

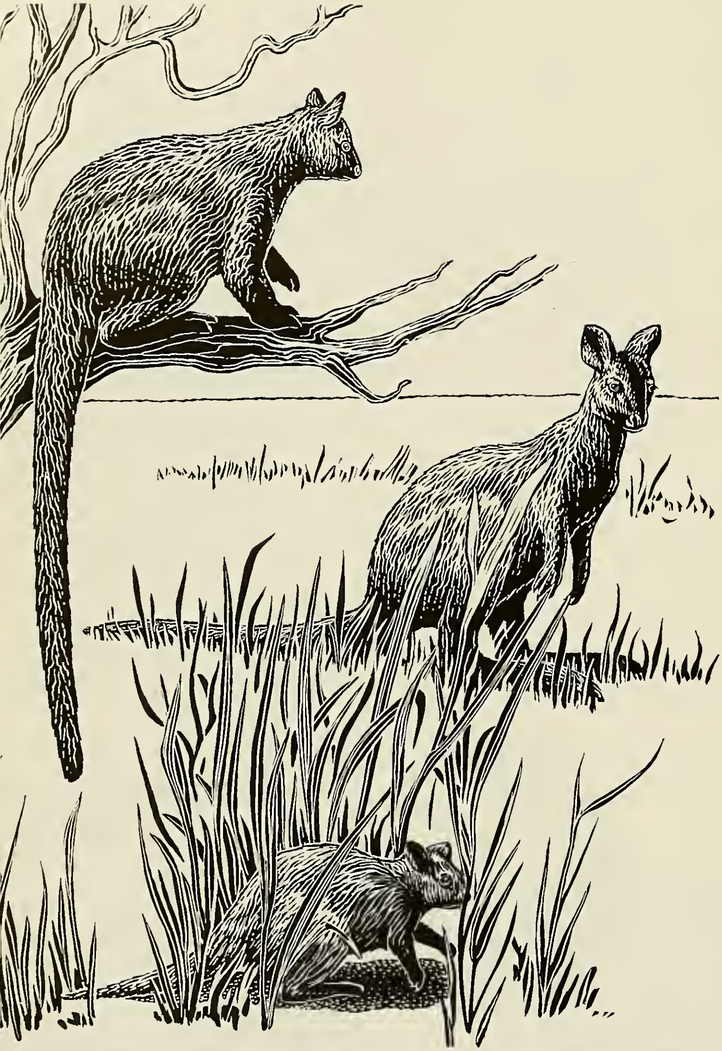
The fourth objection was the absence of intermediate varieties in single formations. If, as assumed by Darwin, evolution had occurred in a slow but constant fashion, we should find, in any formation, a gradual transition between species present at the time of its commencement and the differing varieties or species presumably descended from them and present at its close. This did not appear in Darwin's day to be generally the case, although much invertebrate fossil material was known from a number of formations of marine origin.

Darwin admitted the strength of this argument, but gave a number of suggestions which lessen its force. It is difficult to determine how long a term of years is necessary to effect an evolutionary change from one species to a derived one; possibly many formations did not persist for a sufficient length of time for noticeable evolutionary changes to have taken place in them. Again, to witness evolutionary progress within a formation, it is necessary that the populations present at its close be descended from those found there at its initiation. But it is not at all unlikely that there may have been considerable immigration from other areas, accompanied by extinction or emigration of old residents. Darwin believed (and many geneticists today are in agreement with this conclusion) that the development of a new variety or species, which may eventually supplant the parent type, generally takes place in a rather restricted area, and perhaps in a relatively short time. The chance of finding a formation in which the supplanting type developed is small.



Continuous evolution of one species within single geological formation was also debated as test of Darwin's view.

Above, the sea-urchin, Micraster, found in the chalk cliffs of Britain, is case of unbroken fossil record of development.



Diversity of forms coming from one ancestor in isolated area is shown by three Australian kangaroos: from top, Dendrolagus, Macropus, and Potorous.

The situation may be further obscured by a factor of quite another sort—a man-made one. There is no golden rule by which a paleontologist may distinguish varieties and species. Species are founded by some workers on the basis of excessively slight differences; by others only when obvious major differences are visible. Whether or not specific changes are thought to have occurred within the limits of a formation may depend as much on the working methods of the paleontologist describing the material as on the nature of the fossils themselves.

Now, as in Darwin's day, there is still often no evidence of progressive evolutionary change within a single formation. But, over the course of the intervening century, a number of detailed studies of formations have been made, ranging from the Devonian to the Tertiary, in which careful work has revealed series of finely graded changes in forms from successive levels. Some of this work was done during Darwin's lifetime. As a result, instead of being forced to state, as he did in 1859, that "Geological research . . . has done scarcely anything in breaking down the distinction between species, by connecting them together by numerous, fine, intermediate varieties . . .," he could in later editions say instead: "It has been asserted over and over again, by writers who believe in the immutability of species, that geology yields no linking forms. This assertion . . . is certainly erroneous."

The fifth difficulty is the sudden appearance of groups of allied species. "The abrupt manner in which whole groups of species suddenly appear in certain formations," Darwin wrote, "has been urged by several paleontologists—for instance, by Agassiz, Pictet and Sedgwick—as a fatal objection to the belief in the transmutation of species."

Were this phenomenon a reality, Darwin declared, the objection would be serious. But the objection is based merely on negative evidence, which experience often shows to be worthless. He points out that, for example, Agassiz had maintained that teleost fishes first appeared—and appeared then in abundance—only in the Upper Cretaceous, but that he had later discovered teleosts, in lesser variety, in the earlier Jurassic and even Triassic. Since Darwin's day, many further supposed examples of the sudden appearance—full-fledged—of animal and plant groups have been found to be equally illusory. The weakness of negative evidence can be further illustrated today by cases of supposed extinction. The most familiar example is the recent discovery in the sea off the Comoro Islands of a living coelacanth fish, *Latimeria*, belonging to a group of which no fossils are known in beds later than the Cretaceous; this group had therefore been confidently stated to have been extinct for seventy million years. Still more striking is the very recent discovery by the "Galathea" expedition, off the west coast of Mexico, of an archaic, segmented mollusk type—long supposed (because of negative evidence) to have been extinct since the Ordovician, a period of perhaps four hundred million years.

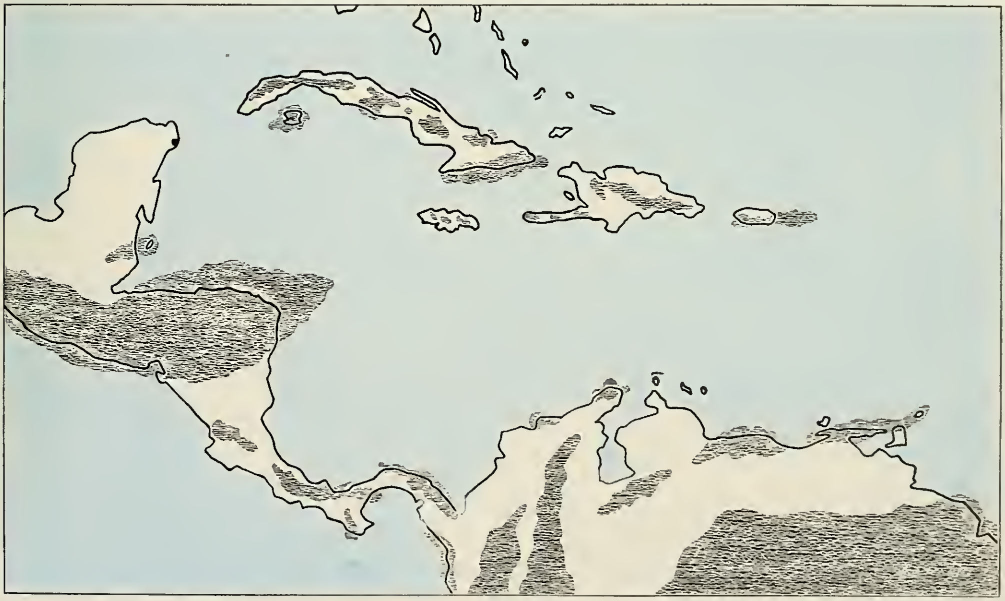
Finally, we have the sudden appearance of groups of allied species in the lowest-known fossiliferous strata. This situation is a special case of the last, and one admitted by Darwin to be a serious difficulty for his theory. From the beginning of the Cambrian up through the rest of the geological sequence, we have an abundant representation of animal life at every stage; even in Lower Cambrian formations, marine invertebrates are numerous and varied. Below this, there are vast thicknesses of sediments in which the progenitors of the Cambrian forms would be expected. But we do not find them; these older beds are almost barren of evidence of life, and the general picture could reasonably be said to be consistent with the idea of a special creation at the beginning of Cambrian times.

To the question why we do not find rich fossiliferous deposits belonging to these assumed earliest periods prior to the Cambrian system," said Darwin, "I can give no satisfactory answer." Nor can we today, although some signs of pre-Cambrian life unknown to Darwin have since been discovered and a number of paleontologists have devoted much thought to the question. Darwin advanced a hypothesis that, in pre-Cambrian days, the world ". . . may have presented a different aspect, and that the older continents, formed of formations older than any known to us, exist now only as remnants in a metamorphosed condition, or lie still buried under the ocean." This hypothesis is none too convincing. Later workers have made various additional suggestions toward a solution of the problem. But even today, we have not completely solved this greatest of remaining paleontological puzzles.

In the part of his work that we have reviewed here, Darwin was strictly on the defensive, parrying objections, based on paleontology, to the theory of evolution. In the second of his two chapters dealing with the history of life, "On the geological succession of organic beings," he advances from a negative position toward a positive one. He attempts to demonstrate that even if, in his day, the fossil record could hardly be used as strong proof that evolution had occurred, it could at least be interpreted as satisfactorily, or even more satisfactorily, in evolutionary terms than under the hypothesis of special creations. But while his refutation of paleontological objections to his theory was very ably done—particularly in view of the inadequate fossil record of his day—this second chapter dealing with paleontology is far from convincing.

Under the Darwinian theory, one would expect to find that new species would come in slowly and successively; that species of different classes would not necessarily change together, or at the same rate, or in the same degree, but that, in the long run, all would undergo modification to some extent. In agreement, says Darwin, are the known facts of the fossil record. The older picture of the past history of life (a few major faunas and floras, following one another in time and each separated from its successor by a major revolution, with complete extinction and appearance of a total new creation) had of necessity been abandoned—with increased knowledge of stratigraphy—by even the most conservatively minded among geologists and paleontologists.

By Darwin's day, it was seen that there had been a long succession of faunas and floras. The content of each differed from those preceding and following, but in some cases the differences were not major. Many types continue through a series of formations, their later representatives differing in a progressive fashion, though to a variable degree, from the earlier ones as we pass upward. In general, animal and plant groups are



Isolation of South America early in Tertiary, some sixty to seventy million years ago, allowing unique fauna to evolve, is shown by shaded area. White area gives the present-day configuration, with link restored about a million years ago.

In addition to directing the Museum of Comparative Zoology at Harvard, Alfred S. Romer is the Alexander Agassiz Professor of Zoology at the same university. Among his numerous writings, two books may be mentioned: *Vertebrate Paleontology* and, more recently, *The Vertebrate Story*. The present article is adapted from his chapter in *A Century of Darwin*, from the Harvard University Press.

of a modest and restricted nature when they first appear, later become more varied, frequently diminish in abundance thereafter—rapidly or slowly—and finally may become extinct. Species or groups once extinct never reappear subsequently; this is, of course, the only result to be expected under the evolutionary hypothesis, but would not necessarily be expected on the theory of special creation. The whole picture presented is, as Darwin says, in harmony with his ideas of evolutionary progression, and is much more difficult to interpret on the basis of special creation.

As already noted, the idea of catastrophic extinction had been abandoned by Darwin's day, but the reasons for the extinction of species, or groups of animals and plants, were obscure (and, to a very considerable extent, are still obscure today). Darwin points out that acceptance of the evolutionary doctrine gives at least a partial explanation. The evolution of new forms can hardly be accomplished without the extinction of older ones. If a new species had evolved from an older one, the more successful characteristics, which have been responsible for its origin through natural selection, may lead to its dominance over the parent type and to that form's extinction. Further, its new and advantageous characteristics may enable it to compete successfully not merely with its own close relatives but also with members of other groups that lead similar lives, and thus cause the extinction of a quite unrelated form.

Related to this question of extinction is a phenomenon noted in the marine Tertiary record by a number of invertebrate paleontologists—the fact that successive faunal changes appear to take place simultaneously (or nearly simultaneously) over large geographical areas. This, says Darwin, agrees well with expectations from the theory of natural selection. New species presumably evolve in a restricted area; but once evolved as dominant forms in one area, the advantages they have acquired would tend to make them dominant in a rapid fashion over broad areas, provided there were no major geographic or ecological barriers to prevent their conquest.

In a discussion of the affinities of extinct forms to each other and to living forms, Darwin overlaps part of his argument in the preceding chapter. There he had pointed out that the general pattern of distribution of known fossil forms was not in conflict with evolutionary interpretation. Here he attempts to go further, and to demonstrate that the evolutionary interpretation better fits the facts. It aids us, he says, to understand how it is that all known forms of life, ancient and recent, make together a few grand classes, and to understand why the more ancient a form is, the more it generally differs from those now living, and often tends to bring closer together two groups that in their present form are quite distinct.

Only on an evolutionary basis is there any necessary reason why the organic remains from any two temporally adjacent periods are more closely allied to each other than to those of other periods, or, Darwin points out, why in a sequence of successive formations the fauna of a given formation need be—as it is—intermediate in character between that which precedes and that which follows. It seemed clear to many paleontologists of Darwin's day, even if they were "special creationists," that the organization of living things had, on the whole, progressed through geological time; this progression is best interpreted on the basis of evolutionary advances.

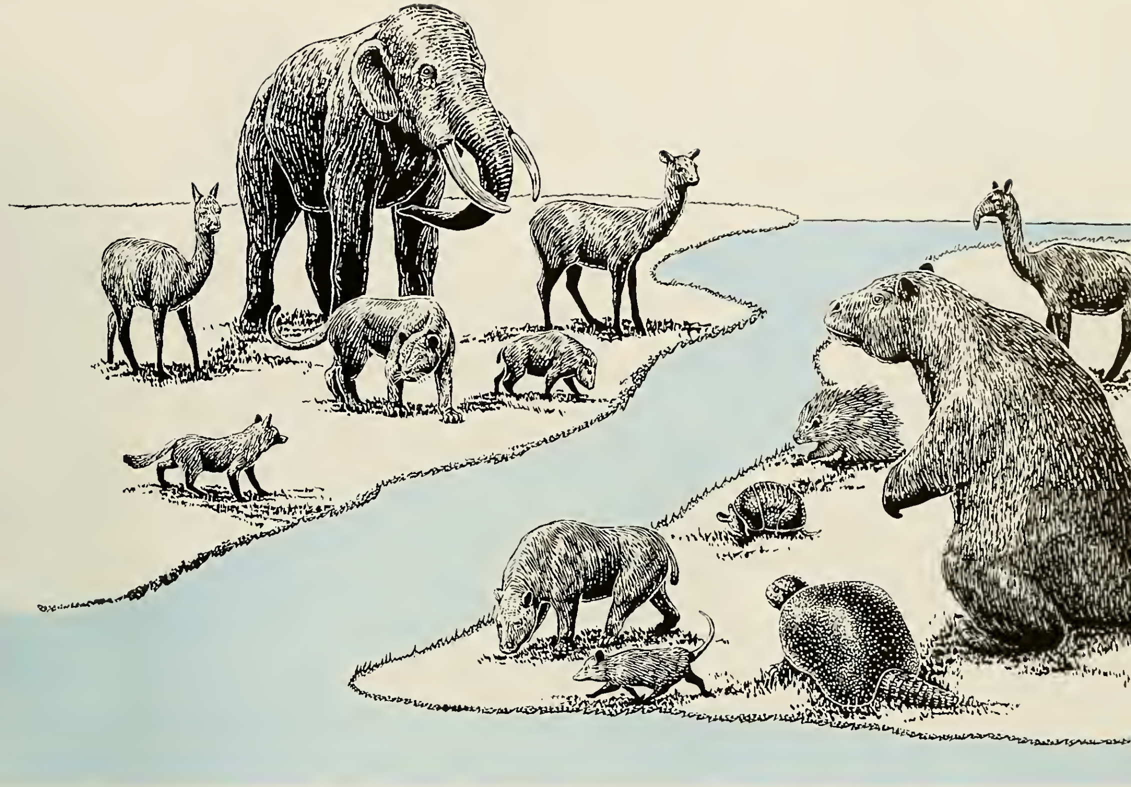
And still further, in at least the later stages of the Tertiary, it is known quite definitely that within the same continental areas the same structural types succeed one another without radical change. Modern Australian marsupials follow allied, although specifically different, Pleistocene marsupials in Australia, and not elsewhere: living edentates succeed similar Pleistocene types in South America, but not on other continents. Such consistency is requisite only on an evolutionary basis.

Darwin thus attempts to show that the paleontological picture is not merely compatible with an evolutionary basis, but is more readily interpretable thus than on the basis of special creation. His arguments are persuasive, but one may suspect that a special creationist would, in his day, have been able to resist them.

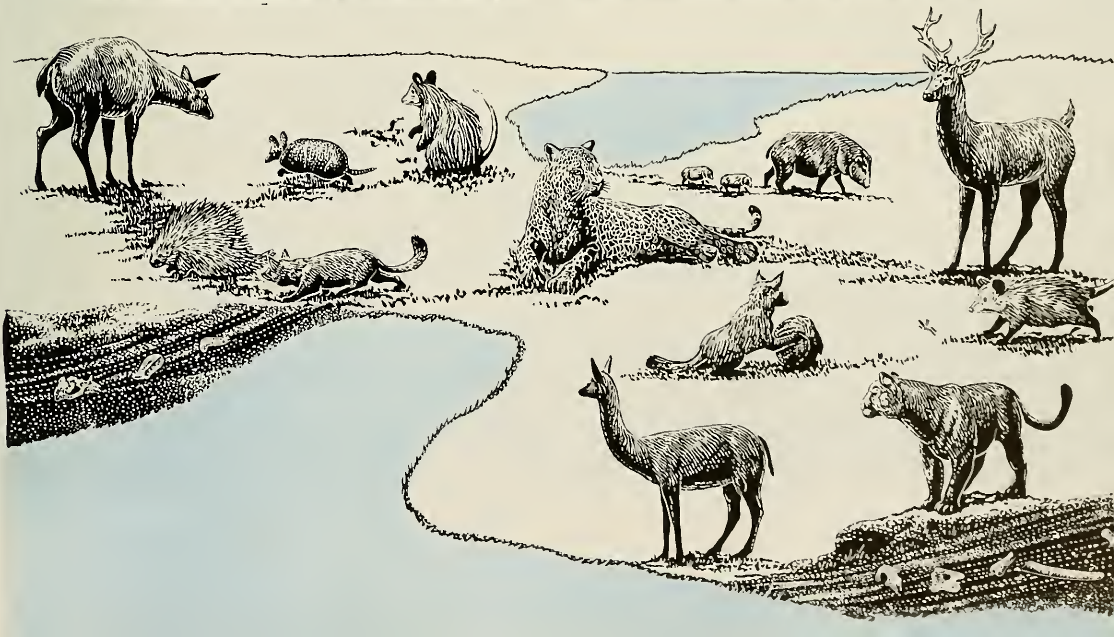
To be sure, the creationist had been forced to abandon the idea of a few successive universal creations and destructions, but he could continue to believe in an essentually continuous creative series rather than continuous evolution of species. And as for the pattern of progress and differentiation, which was beginning in those days to appear in the known fossil record, such a claimant could reasonably argue that, in successive creations, the creator—nature or a deity—might well follow a logical course; that new species created would tend to be shaped along the general lines of the old; and that the general progress seen in successive periods might be compared to the picture seen in the development of modern machines. For example, even though no refrigerator or automobile gives birth to its successor, the "creations" of successive years are of a more and more advanced nature.

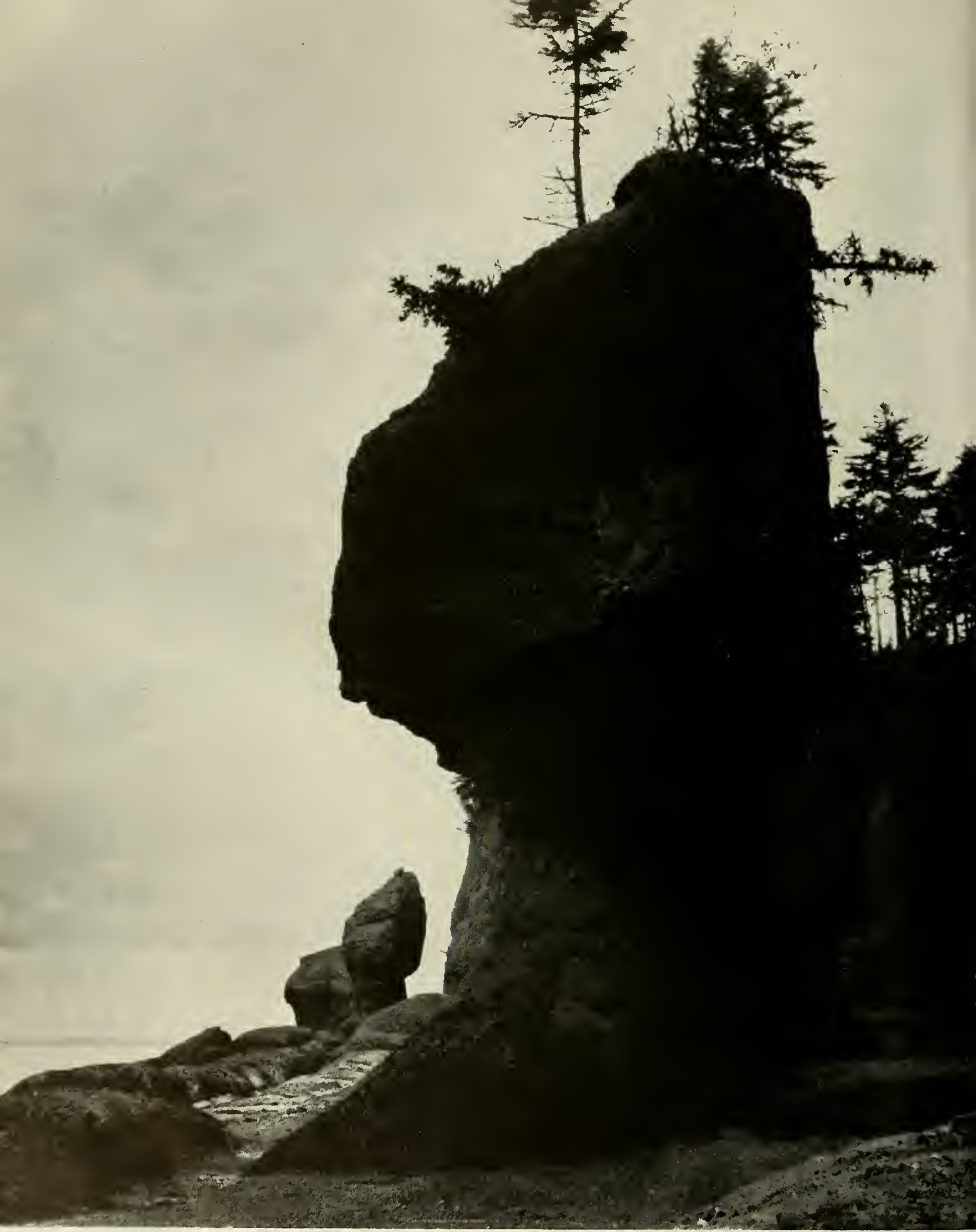
But, despite resistance, a gradual and eventually complete conversion of the paleontologists did take place. Partly this may have been due to the general reasonableness of the evolutionary point of view. In considerable measure, we may suspect, it was due to the constantly enlarging vista of the past rendered possible by further fossil finds. This conversion was well under way during Darwin's lifetime. In the first edition of the *Origin* he remarks that "The most eminent paleontologists, namely Cuvier, Agassiz, Barrande, Pictet, Falconer, E. Forbes, etc., and all our greatest geologists, as Lyell, Murchison, Sedgwick, and so on, have unanimously, often vehemently, maintained the immutability of species." And, in favor of his own point of view, he could say only that his close friend and confidant, Lyell, ". . . from further reflection entertains grave doubts on this subject."

Years later, in the final edition of the *Origin*, the first of these statements remains unmodified. But for the second, he could say instead (no doubt with quiet satisfaction); "But Sir Charles Lyell now gives the support of his high authority to the opposite side, and most geologists and paleontologists are much shaken in their former belief."



INTERCHANGE of mammals between North and South America occurred only about a million years ago as the isolated faunas shown above were re-connected by land bridge via Panama Isthmus. Results to South American mammals, shown below, were disastrous. Some South American forms went north and survived there—e.g., armadillo, opossum, and porcupine, but most migration was in other direction. Some invaders from the north perished, like mastodon; others became dominant. Native ungulates were replaced by newcomers like llama and deer, or slain by carnivores, which found them easy prey.





Bay of Fundy tides have sculptured the sandstone cliffs of Hopewell Cape into grotesque, isolated columns such as the ones, *above*, a few miles from Fundy National Park, in New Brunswick. At high tide, the columns' bases are submerged.

THE MARGINS OF THE RESTLESS OCEAN

Ebb and flow affect both the littoral and its occupants' lives

By Hubert A. Bauer

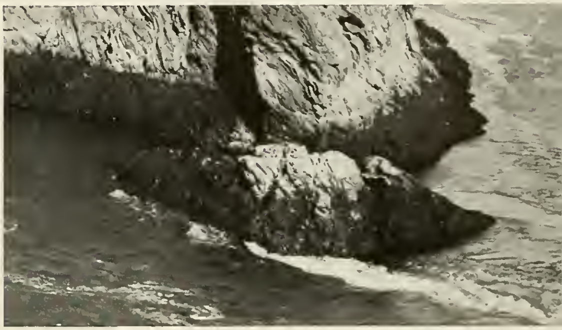
WHILE WE KNOW that the fundamental dynamics of the tides are provided by cosmic forces. astronomy alone cannot explain why the tides we actually experience at the seashore differ—in type. in range, and in time of occurrence—not only from ocean to ocean but also from place to place in the same ocean, often within surprisingly short distances. The classic picture—that two diametrically opposite waves under the moon run round the earth (Natural History, June, 1959)—cannot be said to offer a full explanation of the striking discrepancies to be observed in the ranges and times of local tides.

The semidiurnal tide—one that brings high water at a fairly regular twelve-hour interval—is common around the shores of the Atlantic, while the Pacific shores have tides of the mixed type—in which a lower high water follows each higher high water. A few scattered places on the earth have tides with an interval of twenty-four hours between two high waters (the diurnal type), and. finally, many smaller and shallower seas, such as the Baltic, have no tides at all. or tides of exceedingly small range. These differences in the types of tides—diurnal. semidiurnal, and mixed—point clearly to the actions of hydrodynamic laws.

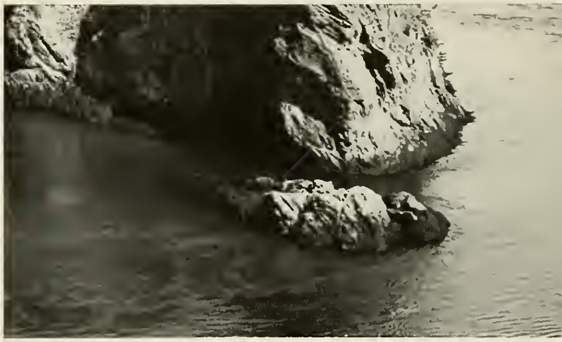
In contrast to such early theorists as Galileo. Kepler, and Newton, tide analysts of the twentieth century hold that the tidal disturbances set up by the moon (and to a much lesser degree by the sun) must be conceived as standing waves; that is. a sort of seesaw oscillation, the amplitude and period of which can be explained by hydrodynamic principles. The type of oscillation set up in a body of water depends largely on all the dimensions of that body's basin—its length, width, and depth. Whenever such a standing wave, traveling shoreward, hits a shallow continental shelf with its bays and inlets, it sends forth a progressive wave. And this latter, progressive wave is identical in nature with any common, wind-caused wave, albeit one of extraordinary length in comparison with its height.

On the Pacific coast of the United States, a tidal oscillation appears to sweep from south to north, so that when San Diego has high water at 6:00 a.m., high water comes at Cape Flattery (Fuca Strait) at 9:00 a.m., at Sitka at 10:20 a.m., and at Dutch Harbor at noon. What appears to be a circular, counterclockwise motion embraces the area between Hawaii and the western coast of the North American continent. It is known as an "amphidromic" motion.

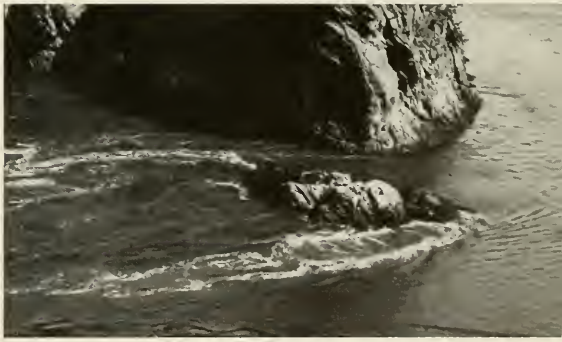
Literally, amphidromic means "around the course." In tidal context, it is indicated by an arrangement of so-called "co-tidal" lines, resembling the spokes of a wheel, which connect points having high water at the same time. The motion expressed by this term may be demonstrated within the miniature confines of a coffee cup. Take a half-filled



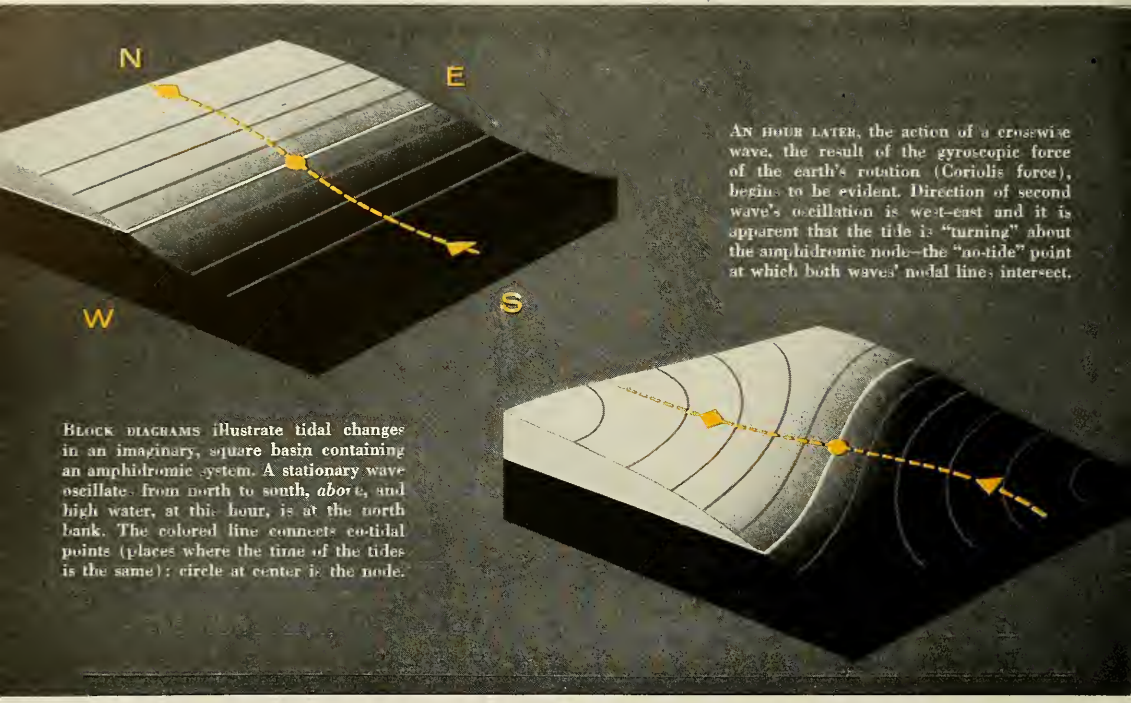
At low tide, St. John River, *above*, runs into Bay of Fundy.



Slack tide precedes remarkable phenomenon—reverse flow.

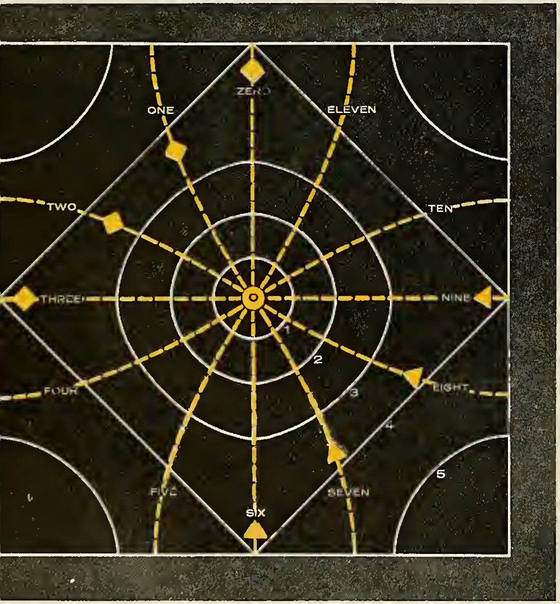


At high tide, the river has reversed. Water runs to left, as is evidenced by the eddies around rock in the foreground.



An hour later, the action of a crosswise wave, the result of the gyroscopic force of the earth's rotation (Coriolis force), begins to be evident. Direction of second wave's oscillation is west-east and it is apparent that the tide is "turning" about the amphidromic node—the "no-tide" point at which both waves' nodal lines intersect.

Block diagrams illustrate tidal changes in an imaginary, square basin containing an amphidromic system. A stationary wave oscillates from north to south, *above*, and high water, at this hour, is at the north bank. The colored line connects co-tidal points (places where the time of the tides is the same); circle at center is the node.

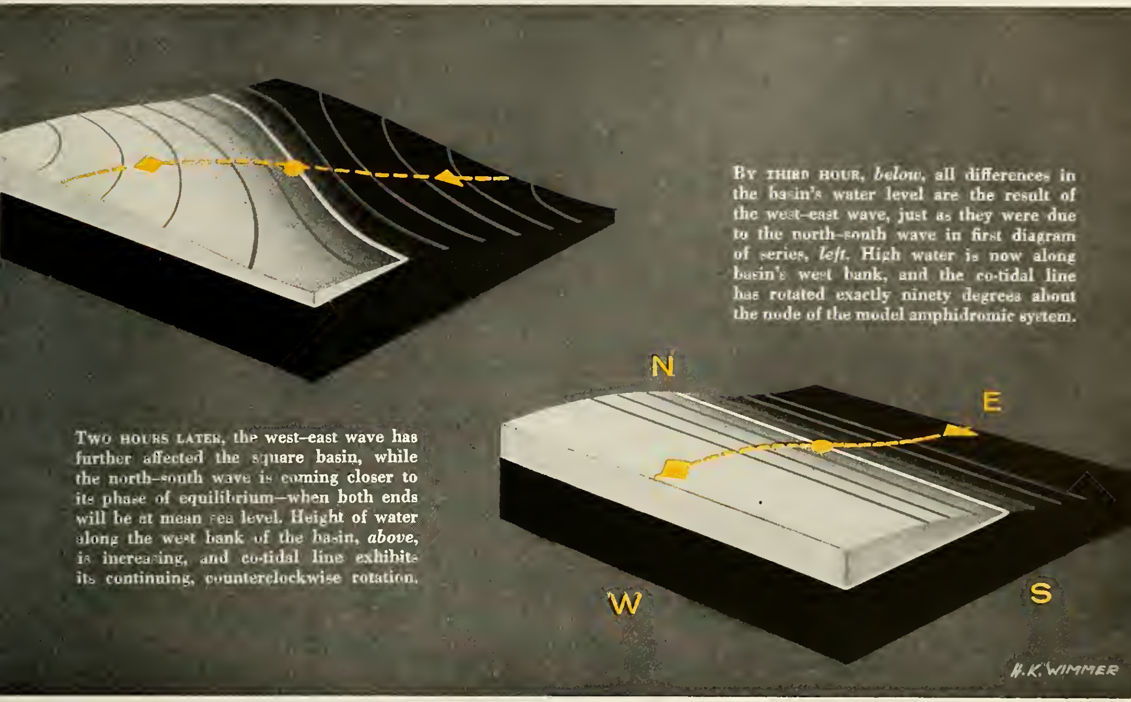


Plan view, *above*, extends sequence in a model amphidromic system through full twelve hours. Rotation of the co-tidal lines is shown in color: the white lines connect points that share an equal range of tide, with zero value at the node.

cup of coffee and rock it back and forth. The motion of the liquid will form a standing wave. Rock the cup in another direction and another standing wave is produced. To combine the two motions to produce a wave interference, swing the cup around in a small circle—as though to dissolve some sugar left at the bottom. Now, a wave laps around the rim of the cup, with a lower point (node) in the cup's center. This is almost exactly what happens in the North Sea (see illustration, *right*).

The rise and fall of the water with the tides is often accompanied by a horizontal movement as well. This horizontal motion is known as flood current and ebb current, or simply flood and ebb. The short periods of change between these two opposing currents are known as slack water. Watch the behavior of a piece of wood floating in ordinary, wind-caused waves. The floating object is carried forward with the crest of each wave, and then slides backward the same distance in the following trough. Apply this observation to the much longer and, relatively, much lower tide wave, whether standing or progressive, and one has a fair conception of the horizontal movement of the water as a function of the vertical tidal range.

Along the coast and in wide, open bays, flood and ebb currents rarely attain speeds in excess of one or two miles per hour. There are, however, narrows—as along the shipping lanes to Alaska—where even good-sized steamers must anchor and wait for slack water. Such strong currents—up to ten miles per hour—are known as hydraulic currents. Narrows usually connect adjoining basins that are being filled up at times of high water, which occur



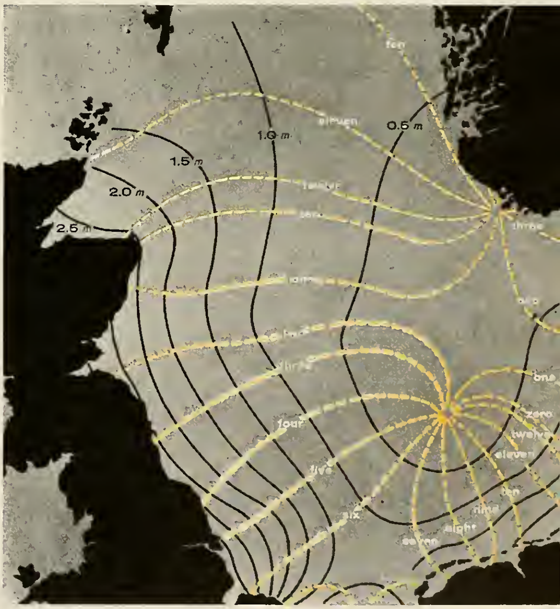
Two hours later, the west–east wave has further affected the square basin, while the north–south wave is coming closer to its phase of equilibrium—when both ends will be at mean sea level. Height of water along the west bank of the basin, *above,* is increasing, and co-tidal line exhibits its continuing, counterclockwise rotation.

By third hour, *below,* all differences in the basin's water level are the result of the west–east wave, just as they were due to the north–south wave in first diagram of series, *left.* High water is now along basin's west bank, and the co-tidal line has rotated exactly ninety degrees about the node of the model amphidromic system.

several hours apart. Thus, while one basin is still filling, the neighboring basin is already starting to empty, causing a difference in level. The water then simply runs downhill from the higher to the lower basin. Seymour Narrows, back of Vancouver Island, and Deception Pass, in Puget Sound, are perhaps the best examples of such hydraulic currents.

The term "estuary" (derived from the Latin *aestus,* meaning surge or tide) is defined as "an arm of the sea at the mouth of a river subject to marked tidal effects." While there are countless such estuaries opening into tided seas, only a few can boast of the most spectacular of all tidal shows, the "bore." The reason for the scarcity of bores is that they require an unusual combination of causes. First of all, the range of the tide must be considerable; second, there must be either an obstructing sand bar at the entrance to the estuary, or a sudden narrowing of the river profile. Both obstacles can cause the waters of an incoming progressive tide wave to pile up, so to speak, until the rising tide is high enough to run "downhill" into the estuary in the form of a fast-moving, precipitous wall of water.

Most famous and highest of all tidal bores is the one that occurs in Hangchow Bay, in China. There, at the time of the so-called "spring" tides—when the lunar and solar high tides coincide—the advancing wall of water may reach heights of twenty feet and more. Near the mouth of the Amazon, a tributary of the Tocantins River is reported to have a bore of fifteen feet. Less spectacular bores exist on many minor rivers—or, rather,



North Sea provides actual demonstration of amphidromic system. Colored, co-tidal lines run out from nodes, where tidal range is nil. Black contours connect points of equal tidal range, with the maximum range being the most distant.

Extremes of high and low tides in the Thames River are seen from identical position opposite the Tower of London.

used to exist—since shifting sands or river improvements often modify or eliminate them. The Petitcodiac River, in New Brunswick, and the Turnagain Arm, south of Anchorage, Alaska, have the two best-known bores on the North American continent.

It is unfortunate that common usage has caused the misnomer, "tidal wave," to be generally applied to oceanic disturbances that have nothing whatever to do with the tides. The very word "tide" (originally, "time"—German "Zeit") implies an event of regular, periodic occurrence, while so-called "tidal waves" are really the opposite of a tidal motion. These highly irregular and highly destructive oceanic waves, caused by occasional submarine disturbances, might better be known popularly—as they are known in scientific circles—by the Japanese term, "Tsunami."

The marks of the tides extend far beyond the confines of oceanic water. For millions of years, the ubiquitous, rhythmic heaving of the seas has left its imprints in a multitude of secondary features, ranging from rock cliffs and sandspits to the adaptations of marine flora and fauna and even the activities of maritime man.

As a geologic agent, with the business of modeling the world's shore lines, the tide may appear to be only a junior partner, working in conjunction with much more powerful agents, such as waves, surf, and wind. But the latter only work on and off at the task of wearing down a cliff here, hewing out a marine platform there, or building up banks and spits. The tide, however, is constantly at work. Besides, its range broadens the front that may be attacked by wind and wave. Thus, wave-cut marine coves have a greater vertical extent on tided cliff shores than in tideless regions. Tidal range determines the height of a wave-built sand bar, spit, or even island; on a flat shore, the width of the strand zone is wholly a function of the range of the tide. There is a saying in New England that "the State of Rhode Island consists of two counties at high tide, and of three counties when the tide is out." Despite this obvious exaggeration, there are regions of the world where the flood area of a tidal foreshore may well approach or even substantially exceed the dimensions of an average county.

Tidal currents do a slow but steady job of scouring, transporting, and depositing. Tidal scour, unlike river erosion, is not performed with such tools as the rocks and gravel carried along a river's floor: the tidal currents are too weak for that. Rather, this scour is a sort of negative erosion: these currents prevent the deposit of sediments along linear areas of the sea floor they sweep. The most pronounced effect of such tidal scour is, of course, observed along alluvial coasts, where the floor of the continental shelf consists of loose material, chiefly sand and fine gravel. Most of the tidal inlets between the Frisian Islands, along the southern and eastern shores of the North Sea, are deep furrows scoured out of the sand to depths up to a hundred feet. Off the western coast of Scotland, in the English Channel (Hurd's Deep), and in the Parrsboro Narrows in the Bay of Fundy, investigators have sounded tidal grooves as deep as four hundred to six hundred feet.

The narrow intertidal zone, that disputed realm between land and sea, is extremely rich in varieties and

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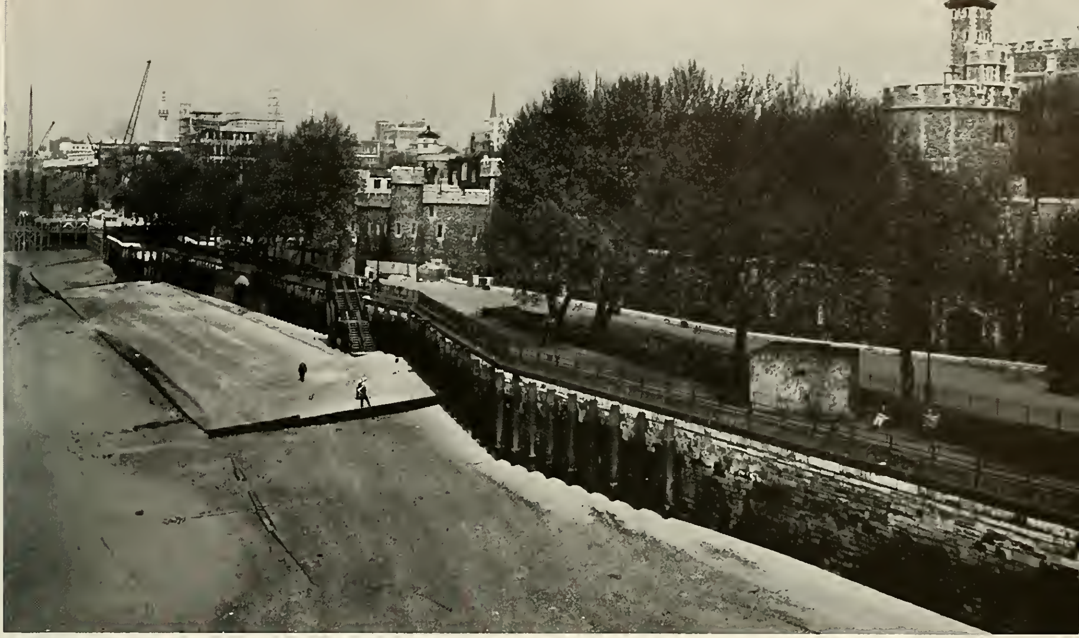
Dr. Bauer is a geographer at Villanova University. Here he continues the discussion of the causes and effects of the tides that started in Natural History's June-July issue.



At low tide in the Thames, *above*, wide margin along the river bank is exposed. Tidal range can exceed twenty feet.

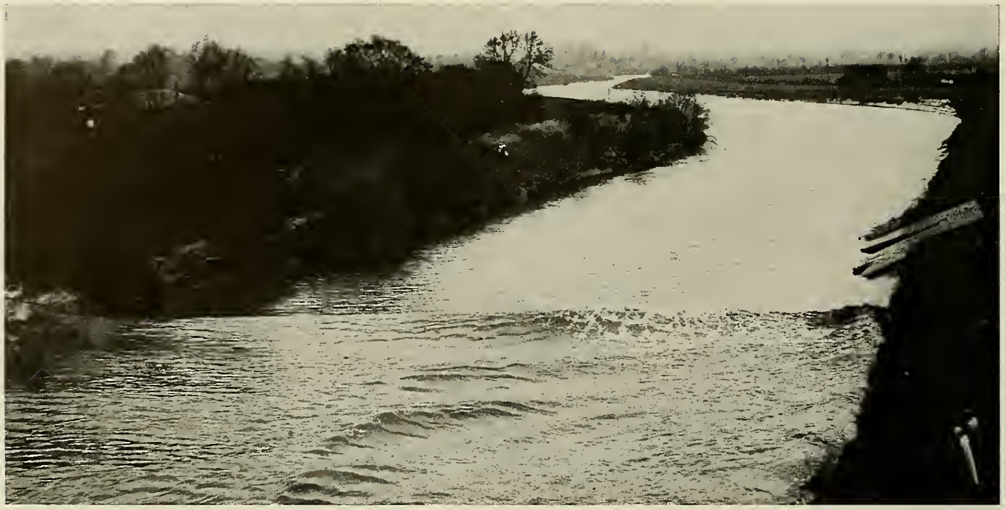
numbers of life forms. These range from algae, sponges, jellyfish, sea anemones, and corals, to starfish, sea urchins, sea cucumbers, and marine worms, plus a variety of snails, mussels, oysters, and barnacles. The life cycles of many of these tidal organisms exhibit such delicate adjustment to the tidal regimen—range as well as current—that they may be said to reflect the phases of the moon.

One member of the tidal fauna that illustrates this delicate relationship between marine life and the tide is the oyster. The areal distribution of oysters is by no means a matter of tidal control alone, but the most successful oyster districts are those where the tide has the most favorable effect upon the oyster's environment. In recent years, when the oyster industry between Cape Cod and Cape Hatteras faced depletion of its beds through overfishing, the U. S. Bureau of Fisheries made exhaustive investigations into the relationship between oysters and the tide. These established the exact function of tidal control in successful oyster-farming: tide currents carry not only food to the sessile animal—they also keep the oyster banks swept clean of sediments (which tend to choke the young oyster), and provide the necessary reduction in salinity.

The spawning season of the oyster is a matter of water temperature—in the United States from the end of June to the middle of August. It was found that the most intensive spawning occurs during the spring tides within the spawning season, evidently due to optimum water temperature. To a large extent, tidal range determines the zone of setting; that is, the final attachment of the larva to a solid object. There are definite levels between high and low water where setting is of greatest intensity. Findings such as these have enabled the oyster farmer to choose the correct time and place for setting. Knowing these factors more exactly, he can control his planting operations and secure a larger supply of precious seed oysters. But this exploitation of a bivalve's tidal links is only one of mankind's contacts with the tide. There are scores of human occupations that either make wise use of a friendly tide, adjust resignedly to the tide as an inescapable part of man's life in a littoral environment, or engage it in a never-ending battle. For the tide is both friend and foe to man.

We may, for instance, call "friendly" the tide that is instrumental in reclaiming lands by controlled periodic silting at high water, a method known as "warping." In this process, the tides slowly and effectively do the work themselves. Man aids in regulating the flow of tidal waters only by providing gaps and inlets, and by producing a sheltered backwater where silt and mud can settle. The term derives from an early method of English dike construction, in which primitive "summer dikes" were started with a row of stakes interlaced, or "warped," with wattles of brushwood, behind which the silt settled and was held.

The idea of harnessing the cosmic forces embodied in tidal motion has always been a challenge to man's imagination. The first primitive use of the tidal range for power came in the era of the grist mill. Such tidal mills sprang up in several favored locations on the coasts of England and France as early as 1790. The best known were located at the River Colne near St. Osyth, Essex, at the River Tamar near Plymouth, England, at the River Ouse near Newhaven on the English Channel, and another at the River Rance in Brittany, France. The Plandome Mill near Manhasset, on New York's Long Island



Tidal bores, such as this one on England's Severn River, are caused by a combination of wide tidal range and sudden narrowing of an estuary. This combination builds up a wall of water that sweeps upriver in gradually diminishing wave.

operated for almost a century and a half grinding grain for a large section of Long Island. All these early pioneers of tidal power shared, of course, the fate of the ordinary grist mill in becoming obsolete soon after the arrival of the steam engine.

The development of modern large-scale tidal power projects appears to be severely handicapped by the growing rivalry of other energy sources and also by the unusually high cost of construction. The history of the "Quoddy" project on Passamaquoddy Bay (at the mouth of St. Croix River, between Maine and New Brunswick) reflects these handicaps. Begun in 1935 only to be suspended in the year following, the project lay dormant for another twenty years before it was finally revived as a joint U. S.–Canadian venture. Today the Quoddy plant is well on the way to becoming the only major tidal power plant in the world. Other, smaller, projects are under construction or consideration on the Severn, in England, and on the coast of Brittany, in France.

Those tides, which, at high water, permit ships of deep draft to reach ports otherwise accessible only to small craft, must certainly be classed among the friendly ones. Of all the tidal ports of the world, the port of London is not only one of the largest, but one that derives the greatest advantage from its tide. A tidal range of twenty feet provides a channel depth of fifty feet at high water, enough for any ocean steamer. While the famous Tilbury docks, thirty-five miles downstream, and other modern dock facilities between London and Tilbury handle most of the incoming cargo, a large amount of freight is still handled in the older, uptown barge harbor. Ships anchor in midstream and are serviced by fleets of barges. For thousands of these, tide currents furnish most of the motive power. At slack water, hundreds of barges can be observed casting off their moorings and drifting to their next destination.

Navigators and fishermen the world over are probably most personally affected by the tide. No ship's master can, of course, be familiar with all the varied tidal features of his many ports of call. The customary pilot's cigar, or, rather, a whole box of them, is only a small token of the relief a skipper experiences every time a pilot steps on to his bridge and takes over. Here is the man who makes a living by knowing all his local tides.

A lifetime of close contact with this intricate element of the environment breeds a surprising degree of intimacy with it; a tide-sense, so to speak. W. M. Davis, an outstanding American geologist and geographer, tells of the life of a people who live in tidal isolation. They comprise the small Frisian communities that cling with inherited tenacity to the so-called "Halligs," a chain of low-lying sandy islands hugging the shores of the North Sea off the coast of Schleswig. They raise dairy cows, beef cattle, and hogs on the sour grasses of their tidal pastures. Their vital connection with the nearby mainland is a regular boat service, but these steamers can negotiate the narrow tidal channels only at high water, which comes fifty-two minutes later each day. Thus, not only the routine boat but practically all the economic and most of the social life of these people is bound to the cycle of the tides. Even the school hours are affected by the daily change of routine, for the boys have to drive the cattle and hogs home from the tidal pastures before the tide comes in.

Speaking of hogs, the Hallig people take pride in their production of excellent breakfast bacon, which should be neither too fat nor too lean. With a twinkle in their eyes, they tell the visitor just what part the tide plays in their famous products. "When the tide is out," they say, "our hogs graze peacefully on their tidal flats. That's when they grow the fat part of the bacon. Then the tide rushes in and they have to run; that makes the lean part." The stern, relentless tide also has its humorous side.

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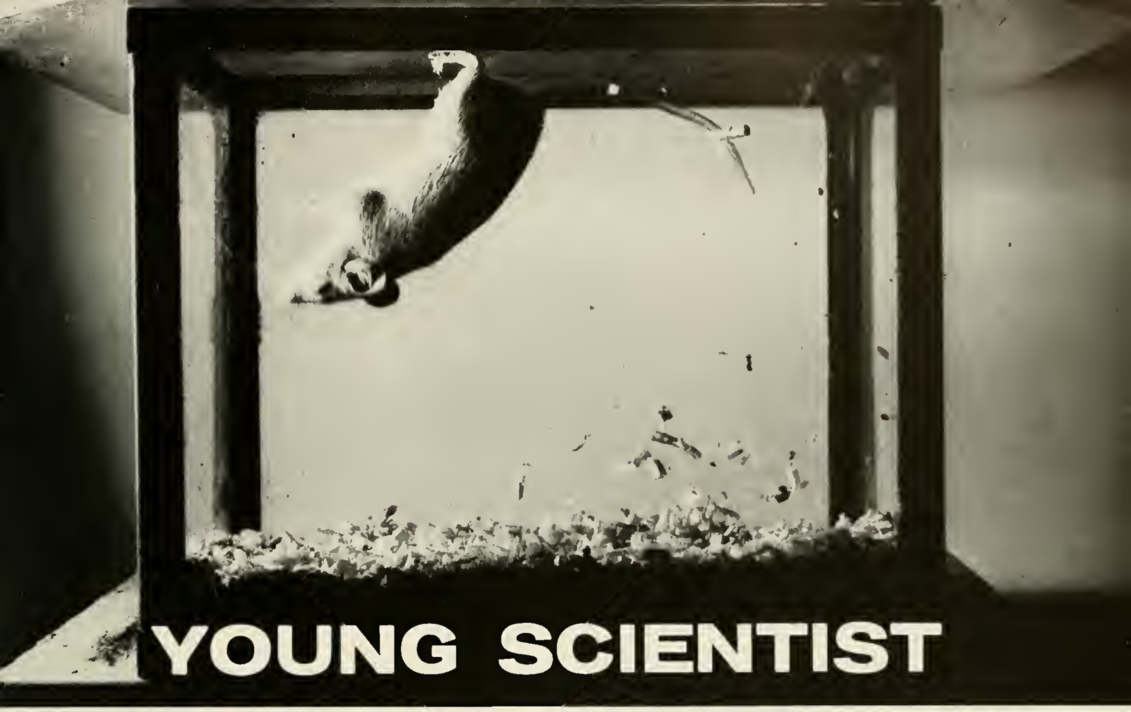

YOUNG SCIENTIST

Observations on development and behavior of "spiny mice"

By Miriam Dick

Acomys, or "spiny mice" as they are commonly known, are native to the Mediterranean region. As Murinae, they are equally related to mice and to rats. Published descriptions of the several different species of *Acomys* are contradictory: the animals with which I conducted my observations are probably *Acomys cahirinus*. Adults are approximately 100 mm. long in head and body, and weigh from 50 to 80 grams. They are a sandy, orange-brown in color; the back is darker and more brownish than the flanks, due in part to the dark tips of the "spines" (actually guard hairs) growing there. The underparts are pure white. The entire tail is about 100 mm. long.

The *Acomys* are not structurally hardy. Their vertebrae are brittle, which causes the tail to be particularly fragile. Two of my animals have only half their tails left and one is entirely devoid of tail: their behavior has not been changed.

Beyond description and classification, *Acomys* had been little studied and no behavioral observations had been made. I undertook as my Science Talent Search project the preliminary study necessary for future behavioral investigations. My first objective was a study of development in newborn *Acomys*. *Acomys* litters usually number two or three pups. I started observations with a litter of two female pups, born on August 26, 1958. Their combined weight at birth, 11.8 grams, was nearly one-fourth of the mother's weight.

Miss Dick, a New York high school senior at the time of these studies, is now a Swarthmore College freshman.

The eyes were closed at birth: they opened on "Day Two" and remained open. Since adult spiny mice will "freeze" at a sudden sound, I tested the pups' hearing by looking for a startle reaction. The first positive reaction to sound I observed occurred on "Day Three." The animals may have been able to hear earlier, but were unable to react noticeably, since they were inactive.

I used various procedures to determine the pups' agility. On "Day One," when placed on their backs, both animals righted themselves immediately, and both were also able to cling to vertical or inverted mesh in their cages, although one did not walk on the inverted surface until "Day Two."

As more mature pups require less care, maternal behavior indicates development of the young. "Day One," I observed, was the only time that the mother carried the pups. Thereafter, they followed her round the cage.

My daily observations revealed that *Acomys* young develop more rapidly than their near relatives, rats and mice. They hear and see at a much earlier age, and are more agile during the early weeks of their lives. As a result, they require less care from the mother.

During my care of caged adult *Acomys*, I observed an unusual behavior, which I call "somersaulting." This consists of a backward leap into the air. For a moment, the white underparts are uppermost; then the animal comes down headfirst (photo, *above*), and lands on all fours. This somersaulting did not occur with all: the animals in my colony were divisible into three groups: six that somersaulted regularly, five that did so occasionally, and thirteen that did not. I tried to determine under what conditions the animals would somersault. Ordinarily, this jumping behavior would start in late afternoon or early evening and continue at intervals throughout the night. However, if one of the somersaulters was put into a clean cage, it would somersault immediately. This circumstance let me study the activity at any time.

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WITH this issue, NATURAL HISTORY introduces a continuing feature, designed to acquaint its readers with some of the outstanding science projects being carried out by students of precollege level. This has been made possible through the co-operation of Science Service, Washington, D. C., under whose aegis more than half a million boys and girls are active in over 25,000 science clubs in the United States and abroad.

Each year, two programs of scientific competition are conducted by the Science Clubs of America. First is the Science Talent Search, by means of which the Westinghouse Science Scholarships and Awards are presented to forty young people who have conducted original, creative, and interpretive research activities. Second is the National Science Fair, where winners from regional fairs exhibit their research projects and compete for a wide variety of honors and awards.

In October of each year, NATURAL HISTORY will publish the study of one Science Talent Search winner whose investigation has dealt with some aspect of the biological sciences. In December, it will publish a work by a National Science Fair finalist, also in the biological field.

With each study will appear a brief commentary, usually by a member of the scientific staff of THE AMERICAN MUSEUM OF NATURAL HISTORY. These will point out the characteristics of investigation that particularly qualified the selected study as one of exceptional merit.

The commentary here is by Dr. Ethel Tobach, Research Fellow in THE AMERICAN MUSEUM'S Department of Animal Behavior.

The behavior was stereotyped: each animal usually jumped from one or two set spots in the cage. If there was a pause between jumps, the mouse would return to the original point to continue somersaulting. Most of the animals landed close to where they started. One male, however, would often land in the diagonally opposite corner of his cage and then somersault back to his original position. All animals that exhibited the behavior were able to start another somersault immediately: one female, for example, made eleven somersaults in fifteen seconds.

Usually, the water tube was in the center of each cage: the somersaults passed near this obstruction but never seemed hampered by it. None of the animals ever hit the tube, although they had their backs to it when beginning their leaps. Moving the tube to one corner of the cage had no major effect on the pattern of somersaults. Those animals that ordinarily started from that corner merely moved over slightly: those animals that landed in that corner also moved over slightly and did not hit the tube.

THE spiny mice were kept in cages of three sizes, each with a mesh top. The only cage in which they would somersault was the larger individual cage (10" by 6½" by 8"), and each somersault usually fitted the size of the cage. That is, in each jump, a circle was described that nearly touched two walls and the top. When moved from their cages to an open area, the *Acomys* would jump, but would *not* somersault. Thus, there appeared to be a relationship between somersaulting and the size of the cage.

To investigate this possibility, I built two new cage covers, which raised and lowered the height of the individual cages by two inches. Except for that one factor, the environments were identical. I observed the reactions of ten animals (all six of the regular somersaulters and two each from the second and third groups) to this change. Every four days, when the cage was cleaned, the height was altered. The animals were kept in cages of normal height for one interval between a high-cage and a low-cage phase. Observations were noted daily.

Those animals that somersaulted infrequently, or not at all, in a normal cage did not somersault in either of the changed conditions. All of the spiny mice that somersaulted regularly also did so in the high cage, although in different patterns. Some of the somersaults were higher than normal, while others were lower. In the low cage, only two animals exhibited frequent somersaults, and a third somersaulted once or twice. Despite the increased restriction as to height, all three did somersaults that did not touch the top of the cage.

Apparently, cage size plays a role in determining whether the spiny mice will somersault. In a larger cage (14" by 8½" by 10"), none of the animals somersaulted, although left there for twenty minutes. Later, the one female that set a record of eleven somersaults in fifteen seconds lived in this larger cage for over a week. At the end of that time, she somersaulted occasionally: the somersaults were slightly higher than normal, but otherwise followed her usual pattern. I hope to increase cage size gradually to see if there is a maximum height for somersaults and a maximum cage size beyond which it does not occur.

A second aspect of the somersault in relation to the cage was the presence of light. Most of the animals crossed the narrower dimension of the cage in their jump: the cages had been arranged so that the light came in through this narrower dimension. I rearranged the cages so that the light came in from the other two sides, and watched for changes in the somersaults. The animals were unaffected by the change in direction of light.

From my observations, I believe that the somersaulting is a hereditary trait. Although a proper environment is necessary for somersaulting, it does not affect which of the animals will exhibit the behavior. The behavior is not related to age, sex, or weight, nor are there any evident differences in appearance and behavior (other than somersaulting) between the groups. All three of one litter from a female that somersaulted regularly did likewise. In two litters from females that rarely exhibited this behavior, four out of the total of five young never somersaulted and the fifth did so only occasionally.

Somersaulting has been described in literature. Helen King found one waltzing rat that performed "vertical whirling," while one or two animals that somersault have been found among Japanese waltzing mice. Waltzing and related movements are established as recessive hereditary characteristics, but not all animals having the same genetic make-up, waltz. If somersaulting in *Acomys* is controlled by a similar recessive gene, this may explain why only some *Acomys* somersault.

At the same time, I do not feel that *Acomys'* somersaulting is closely related to the waltzing mutation in mice and rats. For one thing, mice that exhibit the waltzing behavior are much weaker than those that do not. This is not true with the *Acomys*. Also, waltzing is an activity, which goes on nearly constantly, with pauses only to eat, drink, mate, and sleep. The *Acomys* somersault for no more than an hour or two at a time. Again, waltzers are deaf and poorly co-ordinated: somersaulting *Acomys* are not.

My investigation of somersaulting in *Acomys* was no more than a preliminary one, but it has suggested several lines of further investigation. Drugs that have caused waltzing in mice may have similar effects upon *Acomys*. It would also be of interest to compare the equilibrium mechanisms in somersaults and non-somersaulters. And it will, of course, be necessary to observe several generations of the animals to verify or discard the hypothesis of hereditary somersaulting.

Dr. Tobach's commentary will be found on the following page.

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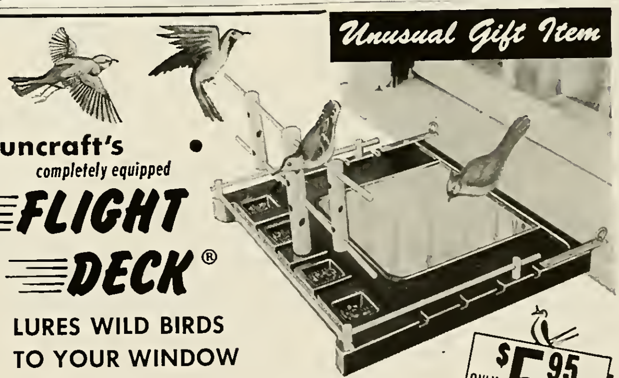

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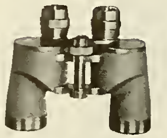

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IT IS ALWAYS EXCITING to study a new problem in animal behavior or to examine an old problem with new insight into techniques or attack. This excitement is enhanced when the animal to be studied is new to the laboratory. In the work described here, the "unknowns" were approached by "known" methods, and the investigator was rewarded with the best possible result: the uncovering of a behavior phenomenon with potentialities for use in investigating important questions in animal behavior.

Here are some questions with which comparative psychologists are concerned:

Is it fruitful, or even scientifically possible, to separate experiential factors from constitutional factors?

How can one explain the continual interaction of past experiences and present circumstances in order to understand and clarify the behavior we observe?

How do developmental processes—which vary in time by stages—contribute to different behavioral patterns in related species of animals?

As this investigator has suggested, the flipping behavior of *Acomys* can be studied in relation to species-characteristic and constitutional variables by means of controlled breeding. As her own work demonstrated, this behavior may be approached in terms of environment and experience. An integration of the developmental approach, which formed a part of Miss Dick's study, with both the genetic and the experiential approaches, should make it possible to search for answers to these questions.

What do we mean when we speak of known methods? Miss Dick has concerned herself with the zoological classification and the ecological characterization of the animal under study—a basic investigative technique in studying animal behavior. Possession of these facts allowed her to plan an investigation of the developmental pattern of *Acomys*' young that would permit a meaningful comparison with the development of related rodents. It also set the behavioral phenomenon studied—the animal's flipping—into the context of known rodent behavior, so further comparisons can be made between and within species. This is a key aim of comparative psychology.

But the utilization of known methods was not all. In addition, the experimenter showed sensitivity to the special qualities of the materials at hand. Such sensitivity cannot be achieved without the sort of assiduous, thorough, and controlled observation of the animal that is evident in Miss Dick's report. Coupled with this sensitivity was a curiosity—a wish to determine "What if . . ."—which is perhaps an inseparable concomitant.

It is her use of known methods, plus the development of sensitivity, that make Miss Dick's study a noteworthy example of an investigation of animal behavior.

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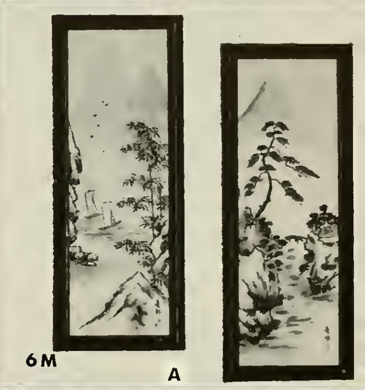

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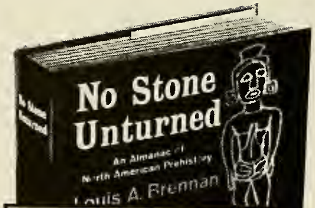

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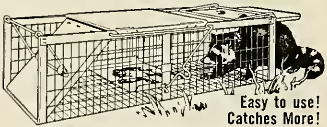

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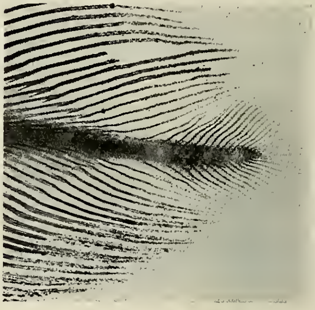
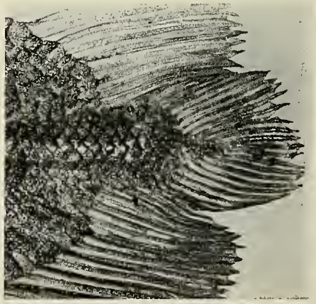


TUFT of *Latimeria* tail, seen in X-ray.

complete brain case, with all the cartilaginous portions in place, and with the related nerves and blood vessels carefully determined, will make future work on this complex structure more meaningful in both the extinct coelacanths and the rhipidistians. There is, unfortunately, no figure of the complete skull and gill arches. It is hoped that this will be included in a future volume. Although the description is generally quite adequate, and pertinent comparisons are made with fossil coelacanths and other fishes, other additional drawings would be extremely useful; for example, the jaw musculature.

The musculature of the paired fins is of particular interest in relation to the transition from fin to limb. Although there are some important differences between the skeleton of the paired fins in coelacanths and rhipidistians, these structures in *Latimeria* are the closest approach among living fishes to the rhipidistian appendages, which did give rise to the tetrapod limbs. In one specimen of *Latimeria*, which lived for several hours after capture, the pectoral fins were observed to be extremely mobile and capable of rotating through 180°. This suggests that they can probably be placed in a forward position when the fish is resting on or moving over the



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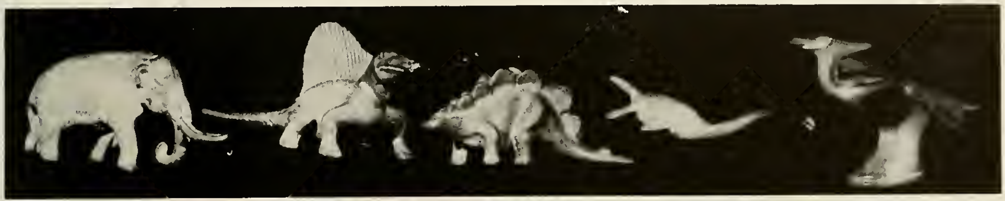

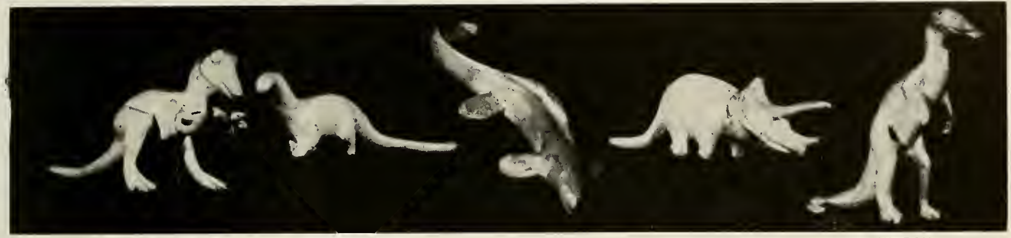

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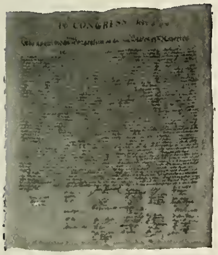

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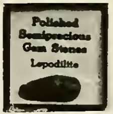

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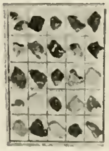

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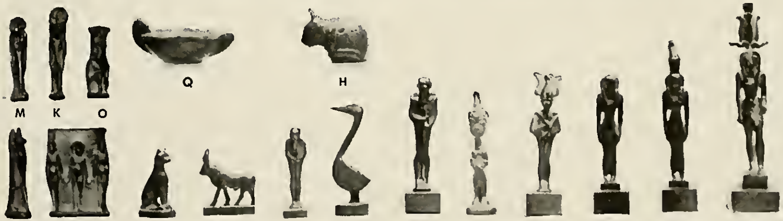

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bottom. The rhipidistians could probably do the same, and the muscle pattern may have been basically similar.

THE Cretaceous ancestry of *Latimeria* is unknown. In some respects, particularly in the pattern of the roofing bones of the skull and snout, it resembles certain Triassic coelacanths more closely than the known Jurassic or Cretaceous ones. But there is a gap of seventy million years in the coelacanth story, and these differences and resemblances are difficult to evaluate. The late Paleozoic and the Mesozoic coelacanths had a large air bladder with a calcified wall, which is frequently preserved in the fossils. *Latimeria*'s air bladder is vestigial and probably nonfunctional. This is perhaps a specialization related to its habitat—the rocky, ocean floor at a depth between nine hundred and fifteen hundred feet. Modifications of this sort, involving mostly the soft tissues and, of course, the physiology, but not necessarily the skeleton, could well account for the differences between a swamp coelacanth of the Pennsylvanian period and its moderately deep water, marine descendant living today.

It will be many years before we know all about *Latimeria*—its embryology, detailed structure, physiology, life history, and behavior. Perhaps the rarity of this fish and the relative inaccessibility of its habitat will make it impossible to acquire all this information. But animals are frequently regarded as rare because we do not know exactly where to look for them, or how to capture them. *Latimeria* may be more abundant than we now realize. All specimens, except the first, were caught on hand lines by native fishermen. This is obviously not a very efficient way to determine abundance. Nevertheless, biologists have long known that there is a minimum population size necessary to perpetuate a species. It would be a curious sort of irony if man were responsible for the extinction of the coelacanth after resurrecting him from the depths of the ocean.

This list details the photographer, artist, or other source of illustrations, by page.

COVER—Lee Boltin.
426—AMNH.
427—"Anatomie de Latimeria Chalumnae".
428—Transactions of the N.Y. Acad. of Sci. vol. 15 no. 6 Bobb Schaeffer.
430-31 Helmut Wimmer, AMNH.
432—Bobb Schaeffer, AMNH.
433—Lee Boltin.
434-39—Max Renner.
440—Helmut Wimmer, AMNH.
442-45—Gordon Smith.
446-51—Al Blaustein.
453—Helmut Wimmer AMNH.
454-55—Star map by Henry M. Neely.
456-63—Kenneth Gosner
464—Top: Robert Gartland, AMNH. Bottom—Kenneth Gosner.
465-66—Kenneth Gosner.
467—Phyllis Morse and Robert Gartland, AMNH.
469—Kenneth Gosner.
470-71—Kosti Ruohomaa, Black Star.
472-73—Helmut Wimmer, AMNH—after Albert Defant "Ebb and Floe: The Iides of earth, air and water".
474-76—British Infor. Service.
479—Lee Boltin.
484—"Anatomie de Latimeria Chalumnae".

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[1] From "Daniel Boone" by Stephen Vincent Benét, Rinehart & Co., I

[2] From "Wild America" by Roger Tory Peterson and James Fisher, Houghton Mifflin Co. Publishers.

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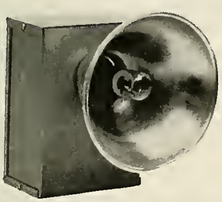

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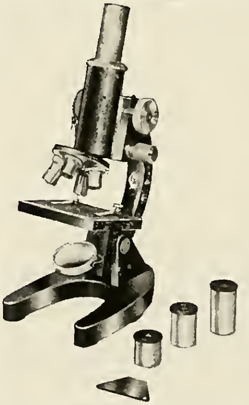

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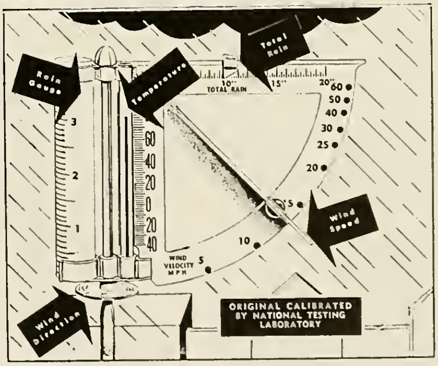

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November 1959

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The diminutive creature on this month's cover is a hydra, named by its eighteenth-century discoverer after the monster in Greek mythology that grew two heads for every one that was cut off; for perhaps the most remarkable aspect of the animal's nature lies in its powers of regeneration. A contemporary scientist, Paul Brien, first demonstrated this by grafting the stained head region of one hydra onto the basal portion of another, unstained animal. The stained material gradually moved down the stalk and off the composite hydra. Brien had thus proved that new cells are always being formed in Hydra's head region and that the older cells are sloughed off the animal's extremities as newer ones move down. For a fuller discussion of this and other experiments with Hydra, turn to the article by Allison L. Burnett on p. 498.

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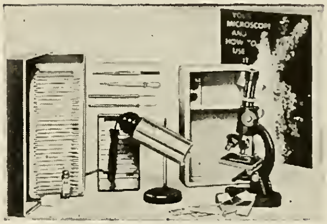

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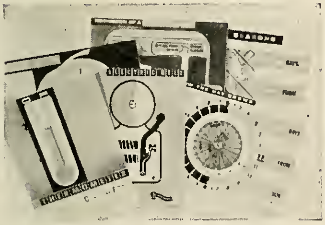

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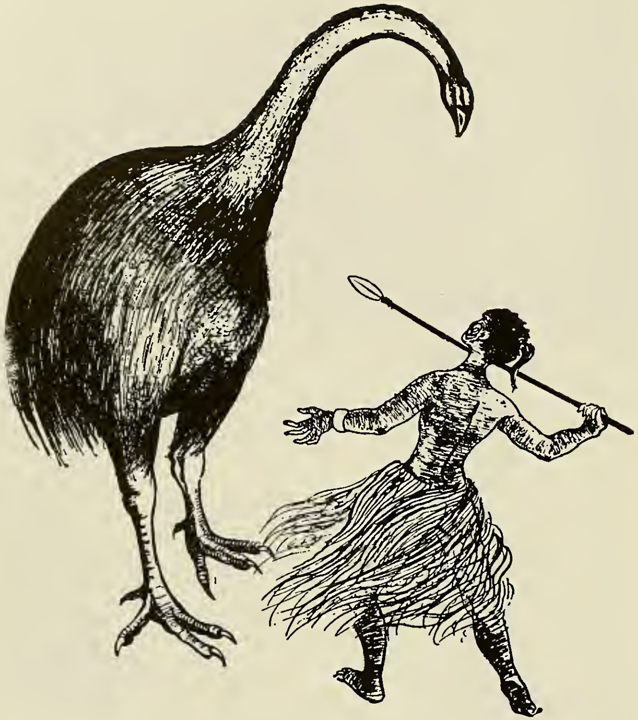


Reconstructed Moa, a large, flightless bird of New Zealand, is from Heuvelmans.

Reviews

CREATURES EXTINCT, LIVING OR FICTIONAL

Reviewed by
George Gaylord Simpson

On the Track of Unknown Animals, by Bernard Heuvelmans. *Hill and Wang, $7.50; 558 pp., illus.*

Every year several thousand kinds of animals are described and named for the first time. It is variously estimated that perhaps a third or perhaps a half of the kinds of animals actually existing are still unknown, in the sense that they have not yet been defined and given scientific names by zoologists. These facts are striking enough, and they emphasize how much work must still be done before we can say that we really know the fauna of our planet.

There are, nevertheless, indications that our ignorance is not quite so extensive as these over-all figures might indicate. To begin with, the vast majority of new animals now being described and still to be made known are insects. Although they are small and often obscure, it is usually no great problem to find new kinds. This is mainly because there are so many insects compared with the small number of entomologists that there simply has not been time to describe them all. Among the less varied groups of animals, such as the birds and mammals, on the other hand, the rate of discovery has slowed down greatly and is approaching zero. There is unmistakable evidence that we really do already know almost (but not quite) all of these more obvious and, on the whole, more interesting animals.

Another point is that most of the "new" animals now being described are not particularly novel—they are so closely related to forms already known that to the nonspecialist they seem almost identical. Now many of them—among birds and mammals, a large majority—are subspecies; and a subspecies is usually an arbitrary or subjective unit. Within broad limits, you can distinguish almost as many of them as you like, and some zoologists do amuse (or aggrandize) themselves in that way. The basic, reasonably nonarbitrary or objective unit in nature is the species. Among birds and mammals, again, and among some other groups, the number of "known" species has actually *decreased* markedly in recent years. This is not because many species have recently become extinct (although a few have), but because many groups earlier described as species are now found either to be subspecies or to have no natural validity.

On these and, unfortunately, on a number of other points, Heuvelmans' enthusiastic and interesting book is misleading. It is certainly legitimate for the writer of a popular book to single out the unusual and the romantic. Heuvelmans has done this skillfully, and in this respect his book is valuable and fascinating. It is not, however, logical to argue that because the unusual sometimes happens it is to be expected. It is downright disingenuous to evaluate all kinds of suspect evidence on that basis and to insist that the improbable is probable or certain merely because it is not impossible.

Right at the start, Heuvelmans sets up a straw man that he attacks throughout the book with all the fervor of a Quixote tilting at windmills. He says that the "official attitude" of zoologists is that the world has been completely explored, that no new animals have been discovered for a long time, and that animals known only as fossils will not be found alive. He has no trouble demolishing those three propositions, but his evidence—as far as it is correct—is entirely derived from the work of the zoologists themselves. Heuvelmans seems to think that the official attitude of zoologists is that zoologists are not acquainted with their own work! He is particularly bitter against the paleontologist Baron Cuvier, who died in 1832 and is not exactly the official spokesman for modern zoology.

Actually, zoologists are so well aware of the inadequacy of earlier *zoological* exploration that they expect any large collection, even from a region geographically well known, to contain some hitherto undescribed animals. They know that new animals are discovered every day because in 999 cases out of 1,000 they are the ones who discover them. They know that groups previously known only as fossils do sometimes (really very rarely) turn up alive, because without exception it is the zoologists who have demonstrated that fact.

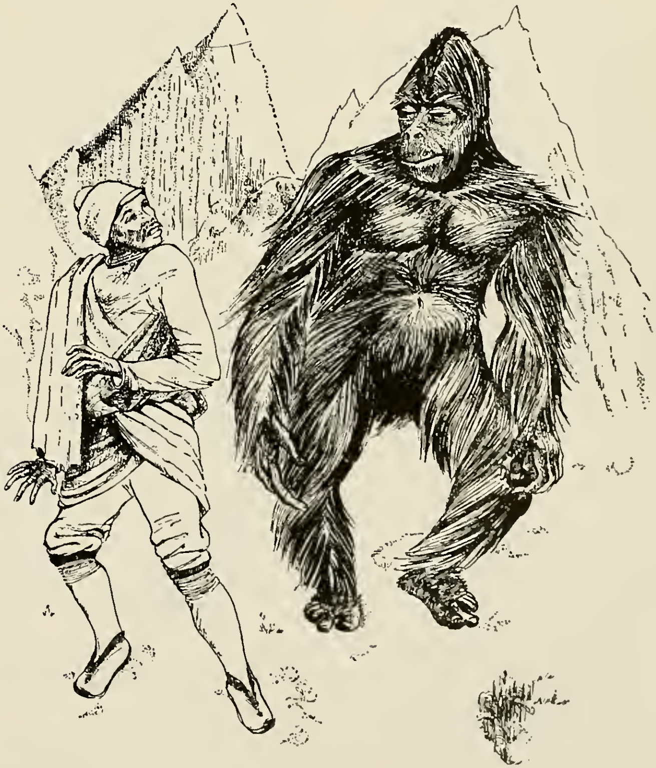
Heuvelmans' intemperate attack on the zoologists, emphasized by still more vituperous introductory remarks by Gerald Durrell, is, in one word, silly. It can hardly be overlooked, because it permeates the book, but it can be discounted, and one can go on to enjoy Heuvelmans' often excellent accounts of some of the more remarkable of the zoologists' discoveries.

As noted at the outset, the many new animals being discovered nowadays are rarely very novel, but there are exceptions. It is, of course, on these exceptions that the romanticist centers attention—and quite properly. There are all levels of novelty. The largest of all living apes was not discovered until 1901, but most zoologists consider it merely a somewhat larger mountain *subspecies* of the long-familiar common gorilla. Grévy's zebra, first definitely identified in 1882 (not exactly yesterday), was a strikingly novel *species*, but it belonged to a genus known since antiquity. The pygmy hippopotamus, now considered a distinct *genus* although manifestly related to the common hippopotamus, was discovered in 1843. It is significant that the dates for increasingly novel discoveries tend to recede in time —although there are exceptions such as the okapi, to be mentioned below. The last really new family of living mammals to be discovered, and perhaps the last ever, was not named until 1939, but it is based on small burrowing rodents at which no one but a zoologist would look twice. (Heuvelmans does not mention them.) Far more striking novelties have, indeed, been discovered still more recently, but they are invertebrates, mostly quite obscure aquatic forms and so outside Heuvelman's inquiry, which is confined to terrestrial vertebrates.

The second major theme of romantic zoology is that of the so-called "living fossils," and Heuvelmans flounders obscurely in his attempts to define this loose popular term. His most stringent definition, to which he does not himself adhere at all closely, is "an ancient type of organism which has survived until today without undergoing any great anatomical change." But man, as far as any creature from the usual concept of a living fossil, has not undergone any great anatomical change since perhaps 100,000 B.C., which seems fairly ancient to most of us. Everything is a living fossil by that standard. There are, of course, less equivocal examples such as the New Zealand tuatara, which has not undergone any great anatomical change since the Jurassic period, perhaps 150 million years ago. (It is fairly typical that Heuvelmans increases the reliably established figure by about a half, assigning the tuatara to the Permian on no known evidence.)

It should be emphasized that the case of the tuatara is exceptional to the point of being unique. Of the many thousands of Jurassic and earlier terrestrial vertebrates it is the *only one* that has survived with little change. Heuvelmans says that the turtles and crocodiles have "hardly changed" since the beginning of the Triassic, but he is wrong both as to their known age and the amount of change.

Another category of "living fossils" includes animals, not necessarily primitive or unchanging, that were believed to be extinct but were later found to be living. Although the examples are few, they are striking, and they cover a broad spectrum. The takahe and moho, flightless rails of New Zealand, were first known from bones in 1847 and one was found alive in 1849. Others turned up periodically until 1898, but thereafter it was believed that they might be extinct. However, a small group of takahes was found alive in an exceptionally remote spot in 1947, and they are probably still living there. Although fascinating, this is not particularly surprising. Near the other extreme is the now famous *Latimeria*, found in 1938, a living representative of a group of marine fishes (coelacanths) well-known as fossils but only up to the late Cretaceous, perhaps seventy-five million years ago.



Abominable Snowman was reconstructed on basis of evidence from many sources.

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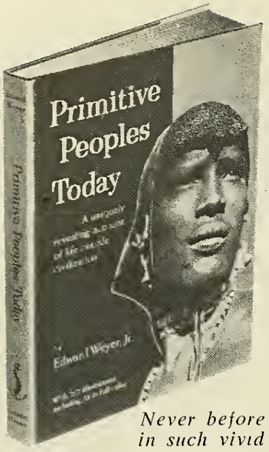

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There are still more remarkable resurrections of one or two invertebrate groups, but the record for terrestrial vertebrates is nowhere near as great. The okapi, first definitely recognized in 1901 although equivocally known earlier, belongs to a subfamily previously known only from fossils, of which the youngest were on the order of five million years old. Of all true discoveries of large, new mammals in modern times, this is perhaps the most romantic, but even so it can be over-romanticized. The okapi is not just like any of its known extinct forerunners, belonging to a quite different genus, and it has a fairly close living relative of the same family, the giraffe, which was familiar to civilized men long before the Christian era.

On this basis, Heuvelmans argues as follows (not so succinctly, but quite along these lines): We know that some living animals belong to groups that have not changed greatly in millions of years. We know also that some groups believed to be extinct for millions of years have proved to have living representatives. Therefore, it is likely that almost any "extinct" group, such as that of the dinosaurs, will turn up little changed in the modern fauna. That is generalizing from the plainly exceptional case, and that is where the scientist, although equally fascinated by the romance of his subject, parts company with the nonscientific romanticizer. It is a matter of judging probabilities. A negative cannot be proved in the full sense of the word. There is *some* probability that there are little men on the far side of the moon, but the probability is infinitesimally small. For numerous reasons that can hardly be discussed here, the probability that there are living dinosaurs is only a little larger.

THAT brings up another category of "unknowns," to which much of Heuvelmans' book is devoted: the many strange animals that have been persistently rumored or purportedly sighted without any specimens ever being submitted to scientific examination. To the pure romantic, most or all of them are real and are, indeed, novel unknowns. Heuvelmans, a fair example of both the virtues and the faults of that school, generally reaches such a conclusion as "certain." To the scientific zoologist the conclusion is certain (100 per cent probability) only when a genuine specimen is available for all to examine. Otherwise the probability ranges down toward, although never quite to, zero, depending on dispassionate, hard-headed evaluation of the actual evidence.

Let us discuss just one of the examples that Heuvelmans considers certain and that I consider extremely improbable. Under the title "Apes in Green Hell" Heuvelmans devotes a whole chapter to the supposed anthropoid ape of South America, and his frontispiece purports to show it, "...the only 'unknown' animal of which there is a good photograph."

Now Alexander Agassiz Professor of Zoology at Harvard, DR. SIMPSON is well known for his numerous books.

The chapter starts with four pages of old tales, which range from the fictional (a passage from Voltaire's *Candide*) to the legendary. No one could possibly take them seriously, and indeed Heuvelmans makes no great point of them. The discovery for which he does claim complete credence was supposedly made by the Swiss zoologist François de Loys in 1920, near the border of Colombia and Venezuela. According to Loys's story, he killed one of two animals seen, propped up the dead body, and photographed it. Loys stated that the beast was larger than any known South American monkey and that it lacked a tail, which all known South American monkeys do have. On the basis of the photograph and these statements, Professor Georges Montandon "identified" the animal as a new member of the anthropoid apes (all of which are otherwise confined to southern Asia and Africa) and gave it the name *Ameranthropoides loysi.*

NOW everyone, including Heuvelmans, who has examined the photograph with even meager competence agrees that it looks like a well-known and common South American spider monkey. Heuvelmans does suggest a few minor differences, but these supposed distinctions either are not really visible in the photograph or are known as variants among spider monkeys. The only reasons for thinking the animal in the photograph is not a spider monkey are that it is supposedly larger and tailless—factors both of which depend on Loys's unsupported word. Neither can be established from the photograph itself, and is not this an odd circumstance? Loys knew that he had made (or would claim to have made) a remarkable discovery of a large, tailless animal, but he did not bother to establish either peculiarity in a photograph, as could easily have been done at the time.

At different times, Loys said the animal was 4′5″ and 5′1¾″ in height. The difference between these two "measurements" is about the same as between the smaller of them and the stature of some known spider monkeys. Moreover, Loys did not bring back a scrap of the animal, not a piece of hide, a tooth, or a single bone. On this, Heuvelmans' only comment is that the expedition cook turned the skull "into a salt box," which disintegrated. Where was Loys when the concrete evidence of the discovery of a lifetime was so oddly destroyed?

Heuvelmans has bolstered this ex-

(Continued on page 544)

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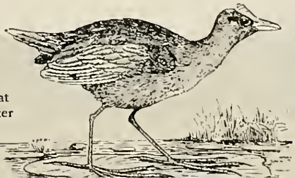

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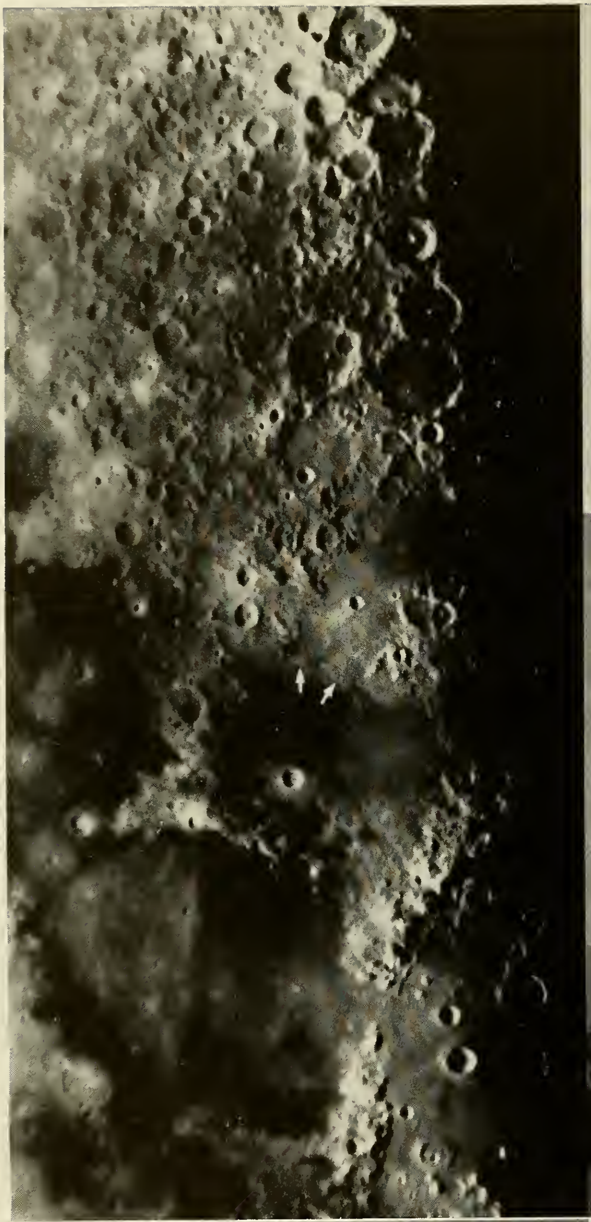

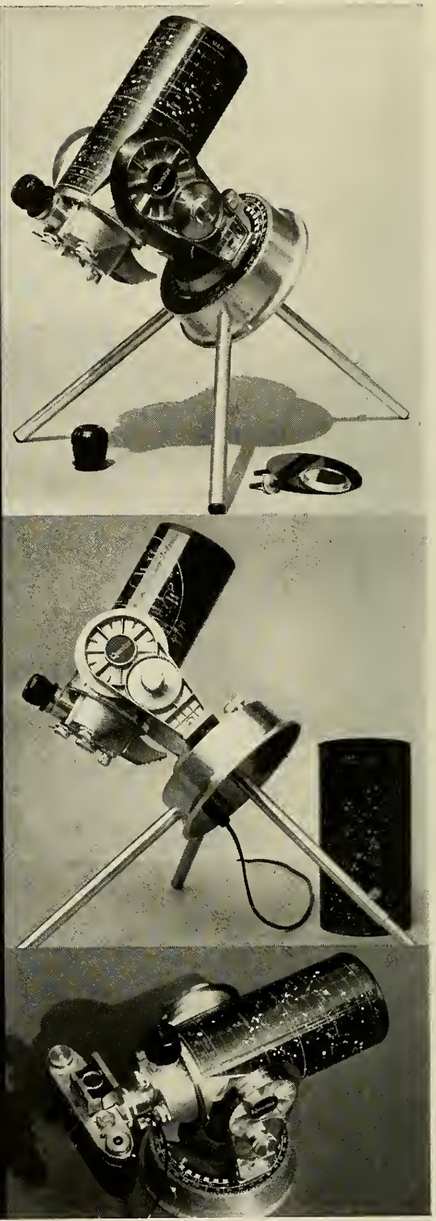

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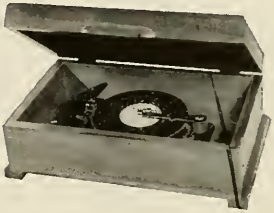

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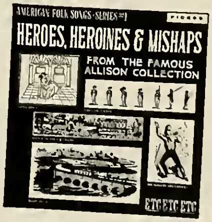
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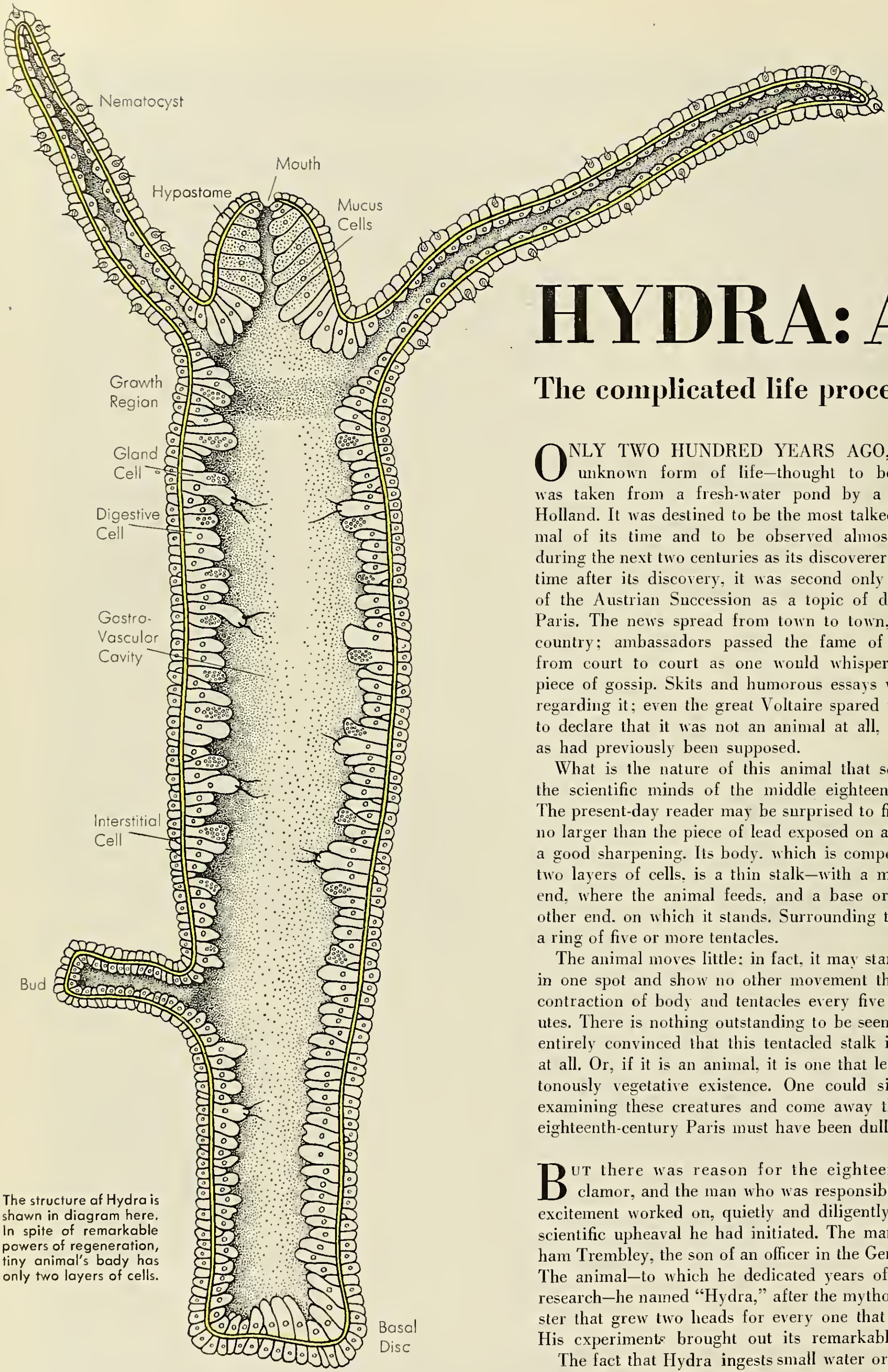


The structure of Hydra is shown in diagram here. In spite of remarkable powers of regeneration, tiny animal's body has only two layers of cells.

HYDRA: AN

The complicated life processes of

ONLY TWO HUNDRED YEARS AGO, an almost unknown form of life—thought to be a plant—was taken from a fresh-water pond by a scientist in Holland. It was destined to be the most talked about animal of its time and to be observed almost as closely during the next two centuries as its discoverer, man. For a time after its discovery, it was second only to the War of the Austrian Succession as a topic of discussion in Paris. The news spread from town to town, country to country; ambassadors passed the fame of the animal from court to court as one would whisper a precious piece of gossip. Skits and humorous essays were written regarding it; even the great Voltaire spared time enough to declare that it was not an animal at all, but a plant, as had previously been supposed.

What is the nature of this animal that so captivated the scientific minds of the middle eighteenth century? The present-day reader may be surprised to find that it is no larger than the piece of lead exposed on a pencil after a good sharpening. Its body, which is composed of only two layers of cells, is a thin stalk—with a mouth at one end, where the animal feeds, and a base or foot at the other end, on which it stands. Surrounding the mouth is a ring of five or more tentacles.

The animal moves little; in fact, it may stand for hours in one spot and show no other movement than a simple contraction of body and tentacles every five or ten minutes. There is nothing outstanding to be seen. One is not entirely convinced that this tentacled stalk is an animal at all. Or, if it is an animal, it is one that leads a monotonously vegetative existence. One could sit for hours examining these creatures and come away thinking that eighteenth-century Paris must have been dull indeed.

BUT there was reason for the eighteenth-century clamor, and the man who was responsible for all the excitement worked on, quietly and diligently, amidst the scientific upheaval he had initiated. The man was Abraham Trembley, the son of an officer in the Genevese army. The animal—to which he dedicated years of painstaking research—he named "Hydra," after the mythological monster that grew two heads for every one that was cut off. His experiments brought out its remarkable character.

The fact that Hydra ingests small water organisms was first observed by Trembley, and this observation helped

By Allison L. Burnett

IMMORTAL'S NATURE

this simple creature are still being clarified by laboratory experiments

to demonstrate more conclusively its animal nature. But because Trembley had only the simplest magnifying devices at his disposal, many intricacies in the ingestion process were unknown to him. What do we see under a modern microscope when a hydra feeds? First, Hydra usually does not go out in search of food, but waits for the food to come to it. However, if the animal is starving, it may—by somersaulting or inching along on its base—shift to another part of the aquarium in search of richer feeding grounds. Once it has attached itself to a substratum, Hydra sits quite motionless, with its tentacles fully extended; in one species of Hydra, the tentacles may extend for half an inch or more.

When a small aquatic organism comes into contact with the tentacles, it is immediately stopped at the point of contact. The prey is still living at this time and often actively wriggling, but it cannot swim away because something holds it to the tentacles. One thinks of a fly striking flypaper: the fly struggles frantically, while the paper remains quite passive. However, the analogy goes no further, because Hydra's tentacle is *not* holding the prey with some sticky substance. If we remove the prey from the tentacles with microforceps and examine it under a magnification of about a thousand times, we find the body of the victim to be pierced by numerous small threads, which resemble tiny spears or harpoons. These threads, called nematocysts, are made by a distinct type of cell in Hydra, especially for the function of food-collecting. When one considers that Hydra's entire body is composed of only two layers of cells, the fact of cell specialization, as seen in a nematocyst-producing cell, takes on special significance.

Let us remove a tentacle from Hydra and examine it, together with the prey. Wherever we look along the length of the tentacle, we see hundreds of these nematocysts, arranged in batteries or nests, with about a dozen nematocysts to a battery. However, the nematocysts in Hydra's cells look quite different from those that have pierced the prey. The thread that pierces the prey has a small sac, that looks like a balloon, attached to one end. In Hydra's cells, the thread is *inside* the balloon. Therefore, on discharge, the thread is somehow everted by an action strong enough to enable the thread to penetrate the tissues of the prey. Although the mechanism responsible for this eversion is still unknown, the most commonly accepted theory is that contact with the prey somehow changes the properties of the sac in such a way that water suddenly enters the sac from the surrounding medium. The sudden inflow of water increases the pressure on the inside of the sac and forces the thread outward with a violent motion. An analagous situation may be imagined by pushing in the finger of a water-filled rubber glove and then squeezing the glove. The inverted finger will evert with great rapidity and force.

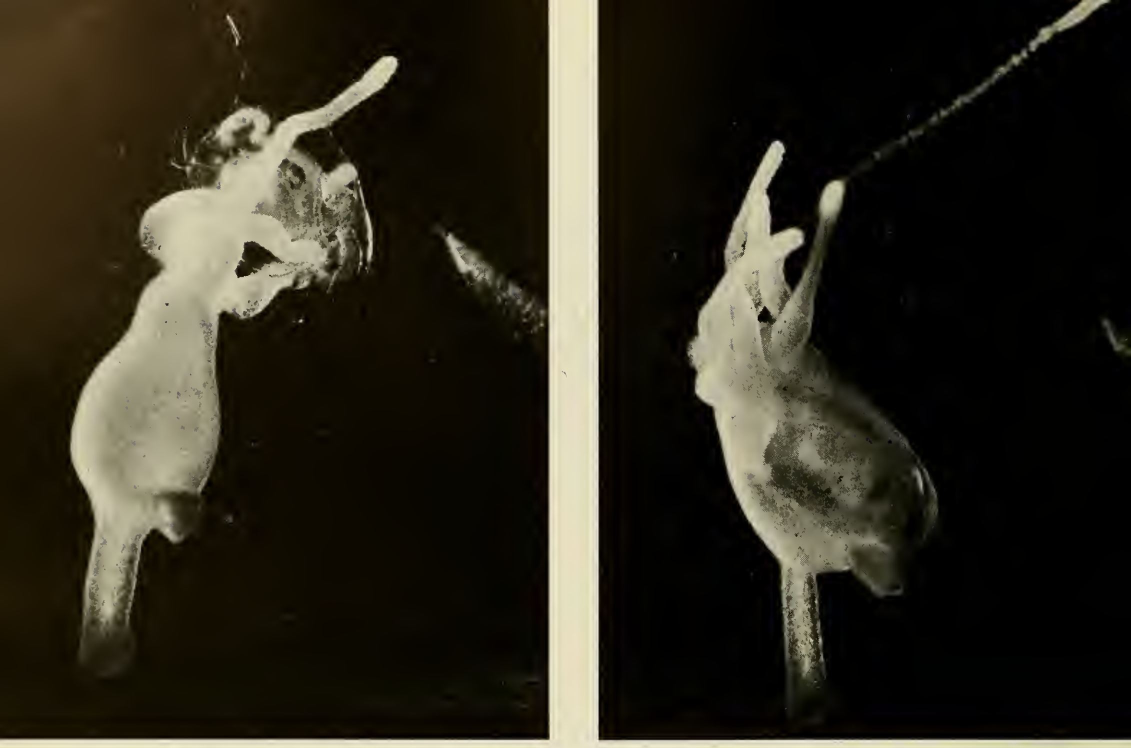
Nematocyst threads alone may not insure the capture of prey, since the prey may be hundreds of times bigger than the nematocyst. Hydra, however, possesses another device to help in food capture. The sac which is found at the base of the thread contains a very strong poison, which is injected into the prey upon discharge and penetration of the nematocyst. Investigators are in the process of analyzing this poison at the present time.

Thus, we can more fully appreciate today what Trembley was unable to—the prey, once it touches the nematocyst, is bombarded by dozens of tiny harpoons, each of which injects a paralyzing poison into its tissues. Not all nematocysts have poison, however: one variety of Hydra, instead of breaking through the prey's tissues, wraps around the prey's bristles, hairs, and spines in the manner of a bola, holding the victim to its tentacles until it can be finally ingested.

Shortly after the attachment of the prey to a hydra tentacle, the remaining tentacles start to move slowly back and forth through the water. A few of them may swing in the direction of the prey and become attached. This movement of the tentacles begins the so-called "feeding reaction," which may be described as follows: the tentacle containing the prey bends toward Hydra's mouth in such a way that the prey may actually come into contact with the mouth. The tentacle straightens out, and then once more the prey will be moved toward the mouth. This process may be repeated several times—although in some cases, it may be lacking completely.

The feeding reaction is followed by the opening of

Dr. Burnett, an instructor in zoology at Cornell, will be spending the present academic year in Brussels, engaged in Hydra research on a National Science Foundation grant.



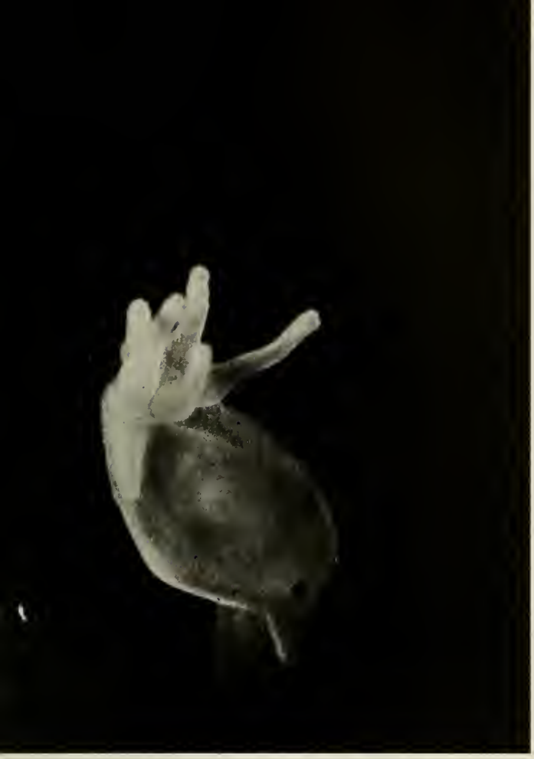
Ingestion of prey begins, *above,* as hydra's mouth opens under stimulus of glutathione released from victim's cells by hydra's nematocysts. At same time, tentacles carry prey to mouth in "feeding reaction." Victim passes down into body

Hydra's mouth, which is located on a small dome in the center of the circlet of tentacles. As the mouth slowly opens, the prey is manipulated in such a way that a portion of it is inside the mouth opening. Then the prey passes slowly and smoothly through the opening—one is struck with the notion that the mouth is gliding over the surface of the prey. And this is what actually occurs, for Hydra possesses no swallowing action, nor do the tentacles push the food into the mouth. The animal simply extends and lets its tissues pass over the body of the captured animal. The ingestive process is facilitated by the fact that Hydra also possesses, on the inner layer of the mouth opening, hundreds of mucus cells, which secrete a slime that lubricates the prey and eases its passage through the mouth.

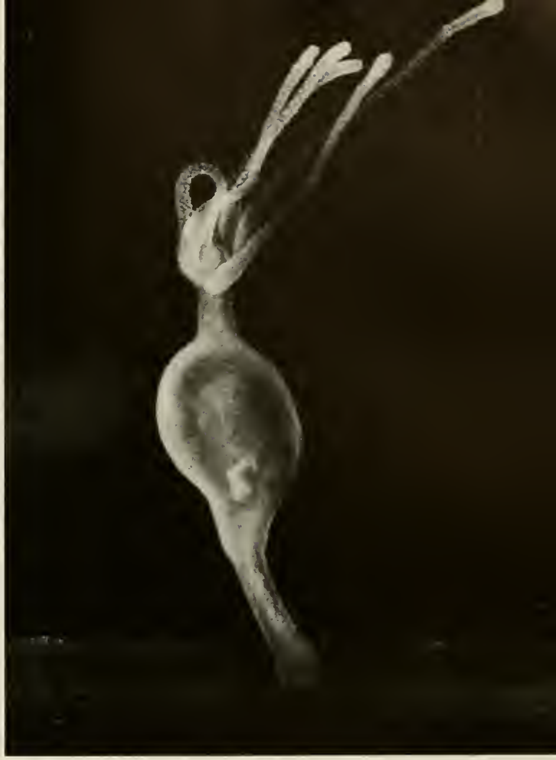
Until very recent years, the stimulus which caused the mouth to open was not known, but the mechanism was finally elucidated by W. F. Loomis, working in his own laboratories in Greenwich, Connecticut. Loomis found that a specific chemical is responsible for the opening of the mouth. This is reduced glutathione—a chemical, found in all living cells, with a relatively simple structure. It can be obtained commercially and, if a few crystals of it are dissolved in a beaker of water and a few drops of this water added to a dish containing several hydra, the animals soon begin the feeding reaction. The tentacles are swung over to the mouth and the mouth slowly opens. Since there is no prey to come into contact with the mouth, the mouth has nothing to limit the dimensions to which it should open. Often, under this chemical stimulus, the mouth continues to open until the animal starts to turn itself inside out. Many animals will go more than a fourth or half the way, and several will turn completely inside out.

Of these latter, a few will die, and a few will succeed in turning themselves back to their normal state. But the rest undergo an amazing process in order to maintain their integrity. Since the cells that are now on their inside were formerly on the outside, and vice versa, regulation to the normal state must be brought about by migration of individual cells to a proper position under the new circumstances. The cells on the inside migrate to the outside, while those on the outside move in. By this switch of the two layers, the inside-out hydra again becomes normal in all respects.

What of the chemical glutathione—does it actually control the feeding mechanism of the animal in nature? The answer is yes. It was previously mentioned that glutathione is found in all cells, but Hydra feeds only upon those animals which release the chemical in a sufficient concentration to stimulate its own nerve cells. The release of the chemical is brought about by the nematocyst, as it enters the body cavity of the prey. Through the hole made by the nematocyst, some glutathione escapes. This causes Hydra to open its mouth. Thus, the nematocyst has a dual function—it injects a poison, and it is also responsible for the liberation of glutathione from the



cavity, *second picture,* and digestion begins. With digestion well underway, *far right,* tentacles are once more sent out



for food. In laboratory tests, glutathione has caused hydra to open mouths so wide they may turn themselves inside out.

prey. Those animals that do not possess a body cavity and release the chemical in only subliminal amounts from individual cells are not eaten by Hydra—which is why one hydra will not eat another. However, if you dip a hydra in a solution of glutathione, another hydra will readily accept and devour it.

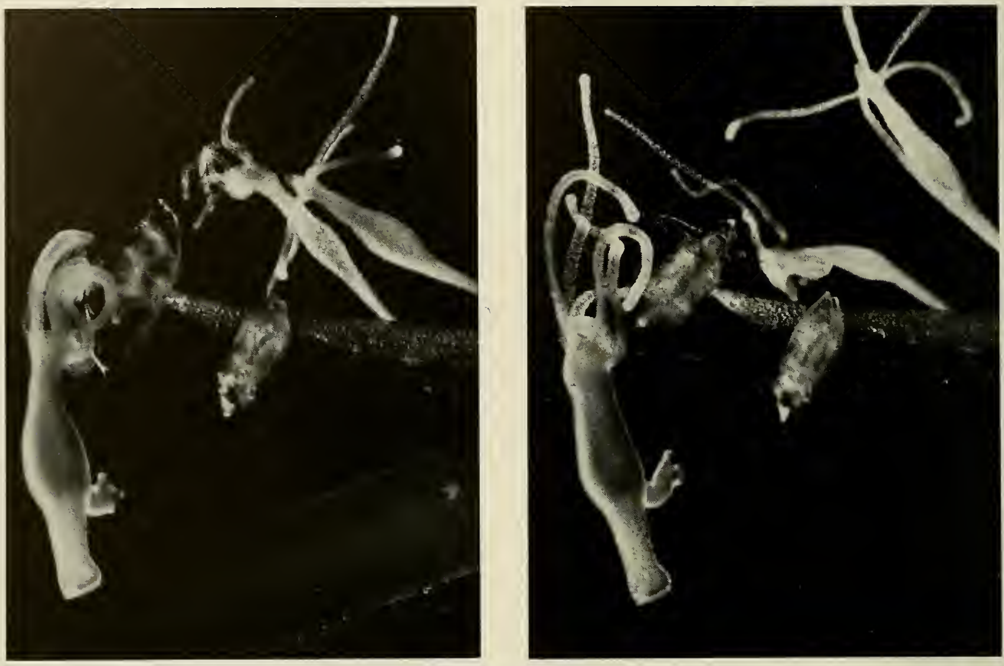
To continue tracing the feeding process, the prey now passes down the stalk of Hydra. Hydra's digestive cavity consists of no more than a simple, blind sac, to which the mouth is the sole opening. Three types of cells are characteristic of its lining. One resembles the kind found around the mouth opening: it secretes a mucous substance, probably for lubrication. The second type, or gland cell, contains many small granules, the function of which has never been adequately determined—although most biologists agree that the granules represent enzymatic substances that will digest the prey. The third type of cell is called a digestive cell. It is responsible for the intake of food into the tissues of the animal.

The mucus cells provide a lubricated pathway as the prey slides down inside the stalk. Usually, the prey is dead at this time, possibly through the action of the nematocyst poison, and within a short time the body starts to break down. Presumably, the gland cells have by now liberated their enzymatic substances into the digestive cavity: at least, if one examines the tissues of Hydra at this time, one notices very few cells containing the secretion granules we just spoke of. While the tissues of the prey are breaking down, the digestive cells go into action. The ends of these cells envelop large food droplets and take them directly within the cell, in an amoeboid fashion. The rest of the digestive process takes place not in the digestive cavity, as in higher animals, but within individual cells of Hydra.

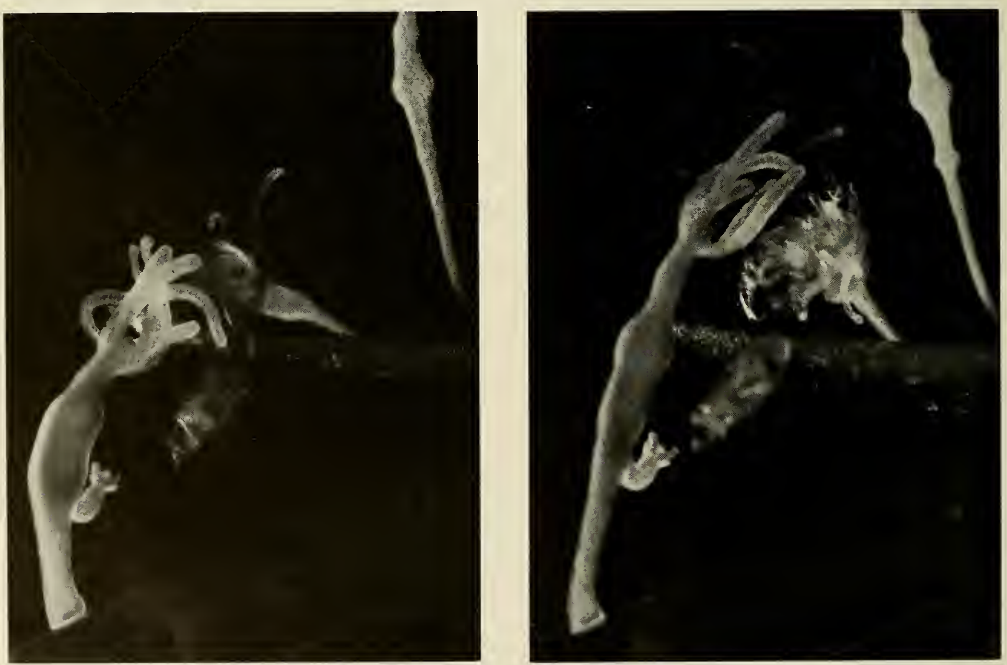
After Hydra has taken thousands of food droplets into its cells, it contracts its body violently, and all the food remaining in the digestive cavity, plus indigestible parts, is shot out of the mouth opening in the form of a tiny white stream, which eventually mushrooms and then disappears. By forcibly eliminating the unusable food products through the mouth opening, Hydra ejects the waste materials far enough not to contaminate itself.

Experiments have enabled us to learn a good deal about the food which Hydra has absorbed within its cells. In general, Hydra takes three types of food droplets into its digestive cells—proteins, fats, and carbohydrates. However, examinations of the tissues of many hydra have shown that the story is not quite this simple: what was formerly thought to be a simple protein droplet has been shown to contain, in addition, two types of nucleic acid—carbohydrate as well as protein. Before considering the role these substances play in the maintenance of an animal, we must describe Hydra's growth processes.

About ten years ago, Paul Brien, working in Brussels, performed an experiment which revolutionized our conception of the growth pattern in Hydra. Brien's ex-



Fight between two hydra over a daphnia is shown in these photographs. Battle took place in a laboratory, but it could easily have occurred in nature, since hydra are often found in dense "blooms," where the competition for food is bitter.



Victory finally comes, *opposite page,* as smaller of the two hydra wrests daphnia from rival. Hydra only attack animals that release enough glutathione to stimulate reaction, and will not turn on each other unless the chemical is present.

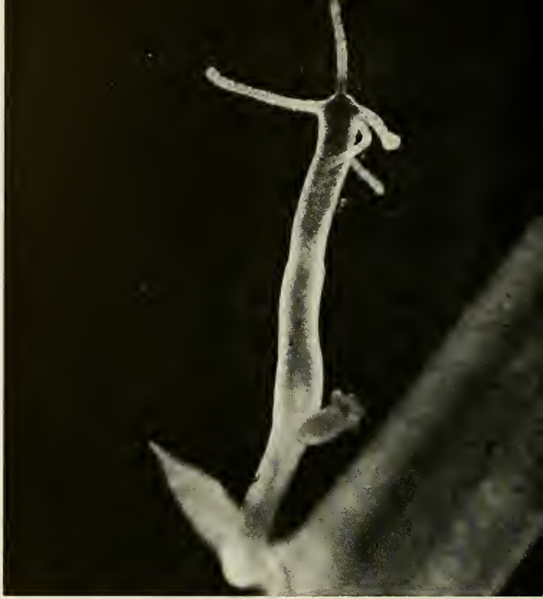
periment, although simple, was an ingenious one. He had noticed that, whenever Hydra moves from one spot to another in an aquarium, it invariably leaves behind a small mucus spot which seemed to be filled with debris of some kind. Upon examining this spot under a microscope, Brien found that the debris was actually made up of dead cells, plus thousands of bacteria. It appeared, therefore, that Hydra was continually losing some of its cells at the base. Yet the animal remained intact. Brien concluded that new cells must arise some place within the animal to make up this loss.

In order to ascertain just where these new cells were formed, Brien stained one hydra with a blue dye which did not interfere with the vital processes of the animal. He then removed a portion including the head, tentacles, and a bit of the underlying stalk from this stained animal. After removing a similar portion from an unstained specimen, he grafted the stained head region on to the unstained basal region, simply by threading together—on a human hair—the pieces to be grafted and thus bringing them into contact. Within twenty minutes to half an hour, the two pieces were firmly united: within an hour and a half, there was co-ordination between the two, disparate halves. This means that, in this incredibly short time, the nervous systems of the two pieces had grown together and their movements had become perfectly integrated.

Brien noticed during the next few weeks that the stained material gradually moved down the stalk until, at the end of three weeks or less, the stain had moved completely off the animal. From these results, Brien concluded that Hydra possesses a growth region just below the tentacles: cell multiplication in this area continually forms new cells. As these new cells are formed, they force the older cells basally and distally to make room for them. When a cell from the growth region reaches either the base or the tip of a tentacle, it dies and is sloughed off. Thus, Hydra is continually renewing its tissues from a single, active growth center: Hydra is immortal!

BRIEN's experiments have been repeated many times in our laboratory, and invariably they were confirmed. However, one interesting observation was made during the course of these repeat experiments. If a stained base is grafted to an unstained upper portion (containing the growth region, mouth, and tentacles) and the new hydra is not fed for several days, then a reversal of the normal migration pattern takes place. Instead of the stained material being sloughed off at the base, as would be expected, the stained cells move in the direction of the mouth—that is, in the direction of the growth center! At present, the mechanism responsible for this extraordinary, reverse migration has not been determined, but recent studies on the nutrition of the animal enable us to suggest a plausible hypothesis.

First, we must consider why the normal growth pattern ceases during starvation. It was mentioned previously that Hydra takes into its tissues three basic kinds of foodstuffs: carbohydrates, fats, and protein droplets. If we examine an animal that has been starved for five days, we notice that, although there is an abundant supply of fat and carbohydrate, the protein droplets are either lacking or present in very small quantities only. We also observe that an animal that has been starving for five days or more no longer reproduces—a fact which takes on added significance when we consider how Hydra commonly reproduces. About midway between the mouth and base, a small protuberance will arise from Hydra's trunk. Within a matter of hours, in the course of reproduction, this protuberance has enlarged greatly, and tiny tentacles are seen to be forming from its apex. After a day and a half, a fully formed hydra is seen to have grown out of the tissues of the parent. The young hydra then breaks free from the parent and begins life as an independent animal. This process is called budding.



STAINING EXPERIMENT shows descent of colored cells from growth region around mouth, *left*, to budding region, *center*,

In the light of how the bud is formed, we can see the connection between the budding region and the growth region. In both areas, rapid multiplication of cells takes place. Also, in a very real sense, *both* areas are engaged in forming a new animal. Therefore, at times when there is no activity in the budding region, it is not surprising that much of the cell duplication in the growth region also ceases. Since protein droplets are the only major food items lacking during this period, we can conclude that protein is needed for cell growth and multiplication.

But it will be remembered that these protein droplets also contain nucleic acids. Nucleic acids are now thought to be constituents of our hereditary material, the genes which are found in all living cells, each species of animal having its own particular types of nucleic acids. Also, it is known that nucleic acids are necessary for cell growth, maintenance, and repair. It would appear, then, that Hydra takes the prey's nucleic acids from the digestive cavity almost unchanged within its digestive cells. Once inside the digestive cells, the nucleic acids are broken down into small molecules and are passed to other cells, where they are built up again into the nucleic acids characteristic of Hydra. When these substances are lacking, as when we deliberately starve the hydra in our experiments, growth processes fall to a minimum.

and finally, eight days later, down to hydra's base, *right.* First performed by Belgian scientist Paul Brien, experiment proved new cells are formed just below tentacles and older cells are sloughed off extremities as newer ones move down.

Now we can return to the problem of why the stained material migrates toward the growth region. The answer may well be linked to the fat distribution in a starved animal. We have found that, although much fat is present in an animal that has been starved for five days, the fat is not uniformly distributed. Instead, it is concentrated in three zones—the base, the budding region, and the mouth—while the other areas of the body have but little. It appears that the distal migration of stained material during starvation represents a process whereby fat, which was previously concentrated, is now being more uniformly distributed throughout the body.

More than twenty years ago, it was recognized that digestive cells in Hydra may pass out into the body cavity and move to other regions of the body, to share the animal's food with these cells. It was also demonstrated that digestive cells often pass large, food-filled vacuoles into the digestive cavity and these vacuoles are carried by currents in the cavity to remote areas—where they break and release food to starving cells. Such a process may be occurring in our experiments during starvation. Cells or parts of cells from the budding region and base may be migrating to the regions between the mouth and budding zone or between the base and budding zone and giving up their food materials to cells that lack these substances.

Once the growth process occurring in Hydra has been understood, it is possible to investigate other aspects of Hydra's biology. One feature that has always interested students is this creature's remarkable power of regeneration—first investigated, of course, by Trembley. He found that if the head of an animal was cut off with a sharp scalpel, a new head was formed in a very short time. Even Trembley was confused by this: in his day, such a regenerative ability was considered a property of plants, not animals. If he cut the head of the animal lengthwise, a new head regenerated on either side of the cut. If each of these heads was cut lengthwise, a four-headed animal resulted. Animals with more than one base may be produced in a similar fashion by cutting the base longitudinally. Many of the lower forms of life enjoy similar regenerative properties, but it was Trembley who first demonstrated that *animals* can possess this capacity.

Trembley's early experiments have been repeated and extended to the present day. In 1897, F. Peebles attempted to determine the smallest piece of a hydra that was capable of regenerating into a new animal. She found that the smallest piece capable of rounding up and forming a sphere with a mouth or one tentacle was one-two hundredths the volume of the intact animal—yet the complete animal is hardly visible to the naked eye.

In 1934, E. Pappenfuss approached the regenerative process from a different standpoint. She cut various Hydra into anywhere from twenty-five to sixty pieces and placed each accumulation of pieces in a small depression, so that they were in contact with one another. From these disorganized masses of individual tissue bits, complete hydra were re-formed. She then repeated the experiment, but this time, before mincing the base of the animal, she stained a fragment of it with a dye. When that hydra "reorganized," she found that the new base was also stained, showing that this tiny, cut fragment had *retained its identity* in the reorganization process! In recent years, H. W. Chalkley has succeeded in obtaining reorganization from even smaller pieces and, in our laboratory, attempts are currently being made to get reorganization into complete animals from *individual* cells of Hydra.

When one considers that two individual hydra cells are capable of fusing, it is not surprising that it is possible to graft part of one animal on another animal.

Inside-out hydra floats amid aquatic plants. Inversion of the animal was caused by addition of glutathione to water.

Again, the pioneer in grafting was Trembley. Today, it is possible, with the aid of dissecting microscopes and microforceps, to thread any two portions to be grafted in less than a minute; and, as was mentioned previously, the grafted portions are firmly united within twenty minutes. But Trembley did not have these modern devices at his disposal. His grafts were performed by placing the pieces of Hydra in a tiny drop of water which he held in the palm of his hand. Without the aid of a microscope, he then dexterously threaded the pieces onto a boar bristle. Trembley performed hundreds of such grafts, and much of the information we have concerning the biology of Hydra—the experiment by Brien that elucidated Hydra growth processes is only one of many examples—was learned by employing this technique.

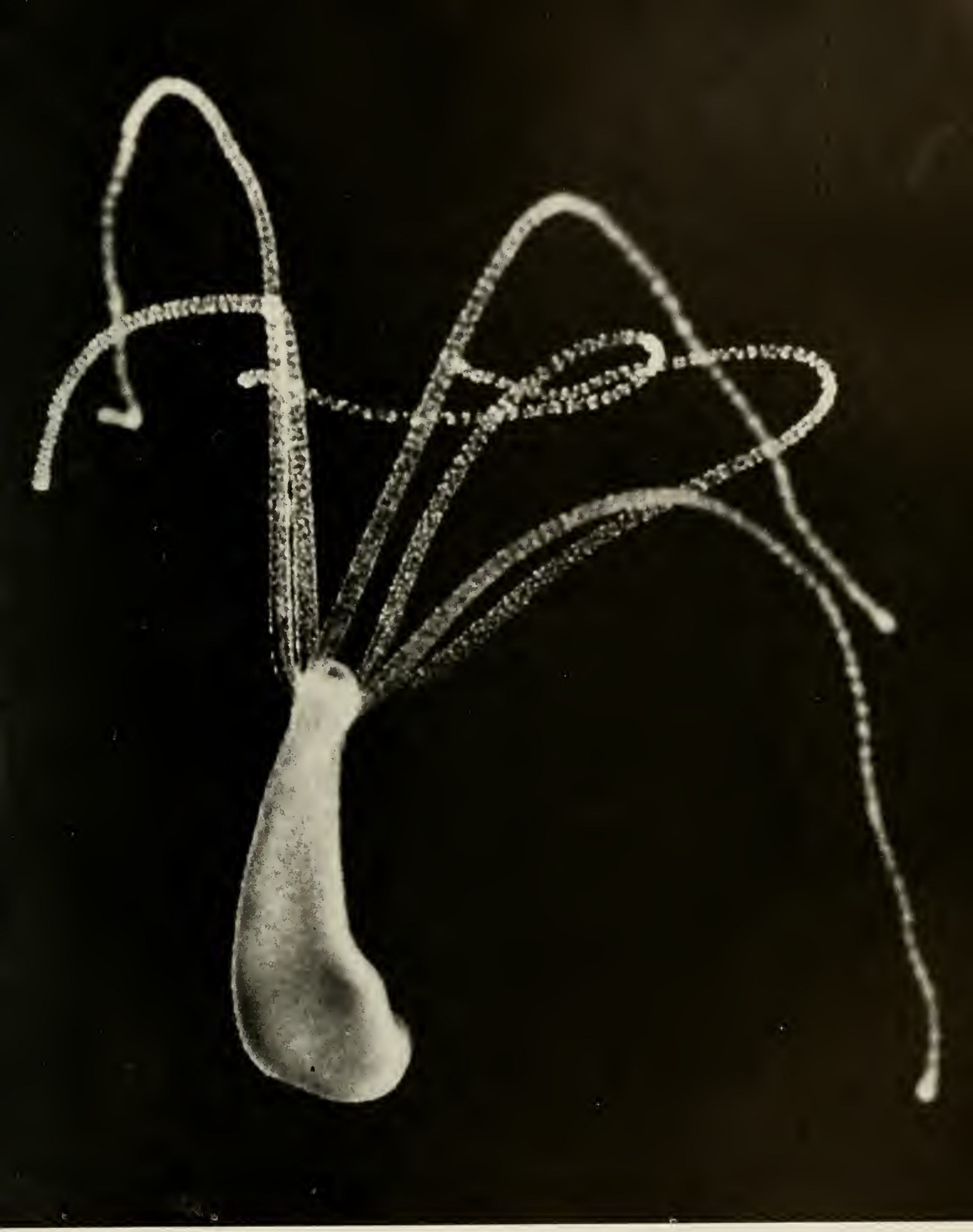
The number of graft combinations appears to be infinite. If two heads are grafted together, a single base arises at the point where the heads meet, and the final outcome is a two-headed animal. If two bases are grafted, then a single head appears at the junction. If the heads and bases are chopped off eight animals, for example, and these eight stalks all grafted together, then a most interesting phenomenon occurs: within twenty-four hours, tentacles are found to be growing out one end of each of the pieces and bases are being formed at the other end. Finally, several bases are holding the organism to the bottom of the dish, and a possible seven or eight heads have their tentacles extended in quest of food. Since a single digestive system extends throughout the entire "colony," all the individuals profit when only one feeds. Such a colony may persist for several days, but invariably the outcome is the same. One by one, individuals begin to separate from the colony in much the same manner as Hydra buds separate from the parent. After a week or so, as many hydra as there were heads in the colony will be seen scattered about the dish.

There is clearly some connection between the process of regeneration and the grafting process—in either case, destruction to the tissues of the animal has been effected and repair must follow. The question may be asked: when the head—i.e., the mouth and tentacles of a hydra—are excised, how is the animal able to produce these structures again from a mere stalk? Part of the answer lies in the simple multiplication of cells that are present after the damage is completed. But this does not fully answer the question, for, as we have already said, there is a great multiplication of mucus cells around the mouth and a high concentration of nematocysts in the tentacles, whereas a simple division of cells in the trunk of the animal—where mucus cells are sparse—would never yield the concentration of mucus cells characteristic of the head region.

The answer to this problem, instead, lies in the versatility of extremely small cells, known as interstitial cells, dispersed through Hydra's tissues. This type of cell is capable of increasing its numbers to great proportions by simple cell division. But also, once a hydra is injured, the interstitial cells begin to transform directly into *other* specialized cell types. They may form digestive cells, gland cells, nerve cells, cells that eventually produce nematocysts, mucus cells, and, under certain specialized conditions, even sperm and egg cells. For this reason, interstitial cells are referred to as totipotent cells. Even in the normal life of the animal, they are constantly transforming and provide for the general maintenance and upkeep of the animal's tissues.

The fact that interstitial cells are necessary for the continued existence of the animal was demonstrated recently by Brien. He subjected his hydra to X-rays which, at a certain critical concentration, destroyed all of the interstitial cells of the animal but did not interfere with the metabolism of other cell types. A hydra thus irradiated was able to feed and even produce what seemed to be normal buds but, after a few weeks, these irradiated individuals died. As nematocysts were being used up in the feeding process, no new cells capable of forming these structures could be formed, either. Gland- and mucus-making cells are also short-lived; both these types must also arise from interstitial cells.

Unfortunately, all interstitial cells seem to be identical and all, presumably, have equal powers. It is impossible to tell by the appearance of such a cell what type it will transform itself into: the mechanism that makes one become a mucus cell and another a gland cell is unknown. They simply respond to the needs of the animal: if gland cells are needed, then interstitial cells transform to gland cells; if nerve cells are destroyed, they transform into nervous tissue. When the nature of these mysterious cells is finally brought to light, we will have gained a great insight into the process governing the formation of an entire animal from a single cell. And such, of course, is the key process we note throughout the animal kingdom.



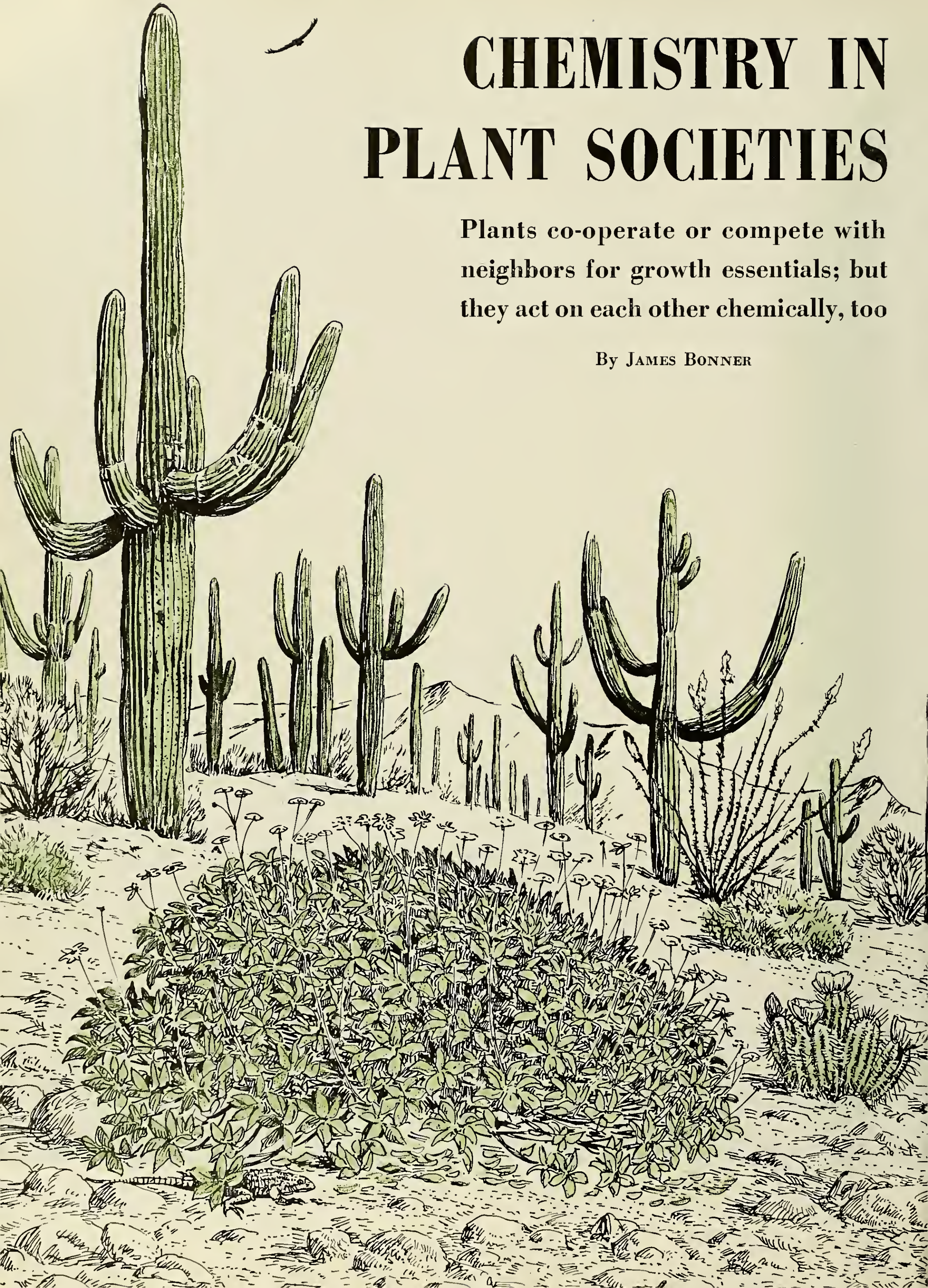
Tentacles outspread, hydra waits for food to come to it—its usual practice, broken only if the animal is starving.

The tentacles contain batteries of nematocysts, microscopic threads with which Hydra pierces prey and injects poison.

CHEMISTRY IN PLANT SOCIETIES

Plants co-operate or compete with neighbors for growth essentials; but they act on each other chemically, too

By James Bonner



PLANT SOCIETIES, like other societies, are made up of individuals living together more or less intimately. The individual plant is surrounded on one hand by individuals of the same species and much like itself, and on the other hand by individuals of different species—individuals that may vary greatly in habit. Since all members of one plant society have similar preferences and requirements, they will settle as closely as the environmental factors will permit.

Individuals of a single species evidently settle in association because they all thrive on, or at least tolerate, the circumstances of a particular habitat. We know from observation of nature, however, that a given area is usually occupied by individuals of varied species. The particular variety of species inhabiting a given area is found to be repeated in many other similar areas, and the constellations thus established are so constant in nature we can enumerate the several species that make up the particular type of society, and can classify and name them as particular communities and associations. Conversely, there are species that we *never* find in proximity to one another, and never found in the same community, even though they may range widely over the same general area. Study of the plant cover of any region reveals the existence of particular plant associations—groups of plants consistently found growing in association with one another—as well as other plants, the species of which do not grow in association.

What is the basis of this segregation of the plant world into communities and associations? It is evident, in the first place, that species may grow in association because they enjoy and thrive in similar conditions of temperature, light, water, nutrients, and soil condition. They may live in association merely because they all like the climate in a given region, much as people of many kinds and origins live in California. According to this view, different types of associations should each be composed of species with different collective requirements as to the environmental factors.

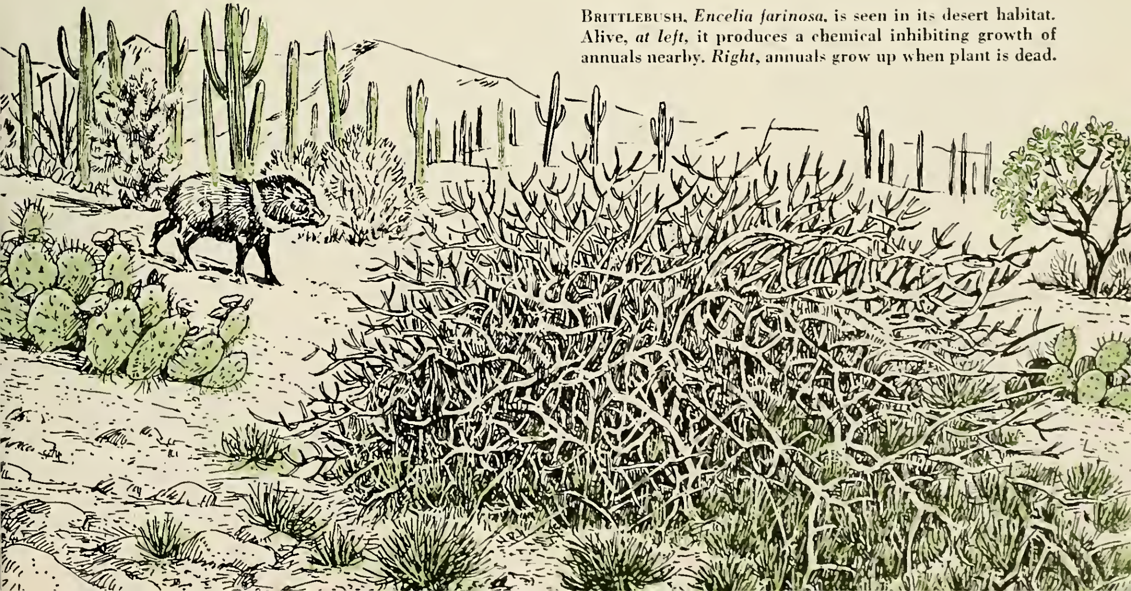
There is no doubt that many, perhaps all, plant associations owe their being, at least in part, to this selection of site by the species best adapted to that site, and a major portion of the work done in plant ecology has centered on assessing the physical factors of a given site—temperature, light, water, and nutrients—which condition a particular association. Thus, the higher plants, like men, have a sociology based on their adaptation to the physical factors of a given habitat, and this might be called the *passive* aspect of plant sociology.

BUT now consider the individual plant in relation to the other individuals about it. Does it have conflicts with its neighbors of the same or different species? Does it co-operate with its neighbors of the same or different species? Can it determine, through the exercise of its own powers, what particular neighbors it will have and how densely it will be surrounded by these neighbors? The answer to all these questions is: Yes, the individual plant does interact with its neighbors, and this interaction may be through either co-operation or conflict.

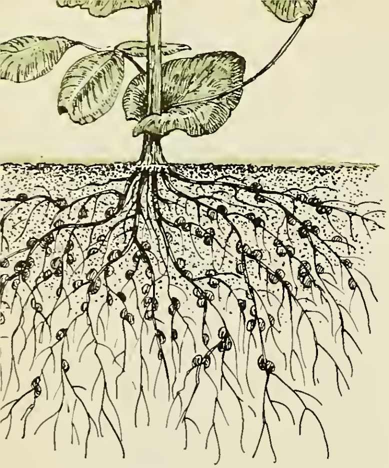
There are many methods by which this interaction between the various individuals of a plant society is realized. Perhaps the most intensively investigated and best understood is competition for some growth essential—for light, for water, or for essential mineral nutrients. The place in the sun of the low-growing shrub is usurped by the taller-growing tree, to the detriment of the shrub; the limited water supply of a field of corn must be shared with the weeds, to the detriment of both. The conflict between the interests of neighboring individuals has, in this instance, what we might refer to as an "economic" basis.

These economic factors will vary greatly in importance, depending on whether the individuals in question are of equal or greatly disparate stature, on whether the roots of the two individuals explore the same stratum of soil, and so on. Also, it is obvious that stable plant communities will tend to be made up of those species whose individuals provide a minimum of economic competition between one another. The constancy of plant associations can be attributed in large part to such minimizing of competition.

Co-operation between individuals



BRITTLEBUSH, *Encelia farinosa*, is seen in its desert habitat. Alive, *at left*, it produces a chemical inhibiting growth of annuals nearby. *Right*, annuals grow up when plant is dead.



Root nodules of legumes—as in pea plant, *above*—provide nitrogen needed by nonlegumes. This is the only certain instance of chemical plant co-operation.

in an association can, like competition, be shown in certain cases to rest on economic considerations. The shade supplied to shade-loving species by their taller-growing neighbors is one example of such co-operation.

This introduction leads us to the question to which this article is principally devoted: Can it be that there is interaction between two plant individuals that is *not* based purely on the kind of factor that I have called economic? The answer to this question is, once again: Yes, both conflict and even co-operation between plant individuals can be, and occasionally are, based on still another mode of interaction. Obviously, plant communities are not susceptible to the interaction of minds and mores to which more complex, animal societies are subject. It is known, however, that in particular instances higher plants can and do interact by means of particular *chemical* substances produced or given off by one plant that affect the welfare of others. It is this aspect of plant life that I have chosen to call "chemical plant sociology."

It is now a well-established fact among biologists that one microorganism may produce a specific organic compound that inhibits other particular organisms, and this is, indeed, the basis of the broad development of antibiotics in medicine. That similar chemical interactions may occur between higher plants was suggested at least as long ago as the time of a Swiss botanist of the early nineteenth century, Augustin de Candolle. De Candolle observed that certain species appeared specifically to inhibit the growth of other associated species, as *Euphorbia* inhibits flax, or as thistles inhibit oats; and he suggested that this inhibitory interaction might be caused by specific chemical substances. However, Baron Justus von Liebig, the great mineral nutritionist, interpreted the same observations in terms of the effects of competition for minerals—that is, in terms of economic factors—and Liebig's view has persisted even down to the present.

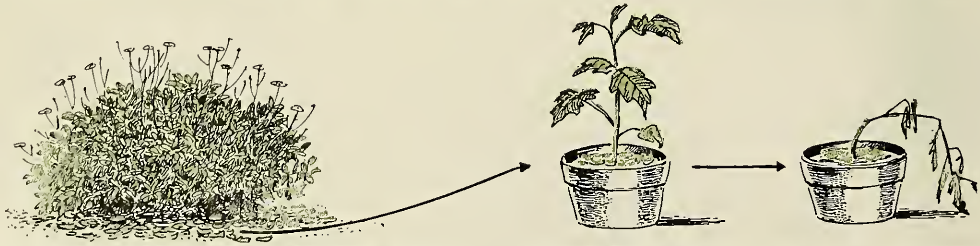
In the years 1900 to 1915, there occurred a considerable resurgence of interest in the growth-inhibiting substances produced by higher plants. Thus, the Duke of Bedford and S. C. Pickering, in England, carried out experiments on inhibiting the growth of apple trees by grasses, while Oswald Schreiner and his co-workers in the United States Department of Agriculture succeeded in isolating from the soil organic substances that inhibit the growth of the plant.

However, in neither these nor in other early investigations was there a clear-cut demonstration that the growth of a particular plant is inhibited—either in the field or in nature—as the result of an identifiable chemical substance produced by a second plant. Such evidence has been adduced only in much more recent times and as a result of much more rigorous experiments than those that had been performed by earlier scientists.

Perhaps the most detailed case of chemical interaction yet worked out is that described by H. Bode, in Germany, and the Belgian C. L. Funke in the years 1939 to 1943. Bode, working in a pharmaceutical garden, observed that in the neighborhood of a row of the wormwood, *Artemesia absinthium*, other species were depressed in growth or actually killed—the effect decreasing with the distance from the *Artemesia* plant, but extending for a radius of at least one meter. Although the growth-inhibiting effect exerted by *Artemesia* obtained for many plants, it did not obtain for all, however: certain kinds, such as a *Stellaria* and a *Datura*, proved relatively resistant.

Artemesia absinthium's inhibiting effect on the growth of neighboring plants was shown in a variety of ways to be *independent* of the effects of competition for nutrients, water, and light. For example, a related *Artemesia* of comparable growth and habit to *absinthium* exerted no such influence in inhibiting the growth of neighboring plants, although it required the same nutrients. On the contrary, the growth inhibitions exerted by *Artemesia absinthium* were shown to be caused by a chemical compound, absinthin, produced in glands on *Artemesia absinthium*'s leaves: the absinthin is washed off onto the ground by rain, and the amount of active inhibitor in the soil is thus continually renewed. The physiological evidence that *Artemesia* produces a specific growth inhibitor active on other species was thus complete.

Funke made ecological observations in the field on this inhibitor's effect on the weeds that grow alongside of *Artemesia*. It was found, as might be expected, that weed species resistant to the *Artemesia* inhibitor in tests are



Basic experiment showing effect of *Encelia* on growth of other plants is illustrated, *above*. Fallen leaves collected from under *Encelia* are placed, *center*, as mulch on tomato. Subsequently, the tomato plant wilts or dies altogether.

Cal Tech's first graduate student to take his degree in plant physiology, JAMES BONNER stayed to be professor of biology at the same institution.

greatly favored in the natural association over those which are susceptible to the inhibiting material. From the standpoint of plant sociology, then, the composition of the vegetation in an *Artemesia* community is at least partly fixed by absinthin, the sociological chemical of *Artemesia absinthium*.

ANOTHER growth-inhibiting chemical is produced by a plant that grows in the Sonoran desert of the Southwest. Examination of the flora of this region reveals that the perennial shrubs usually harbor a vigorous vegetation of annuals in and around the shrub, their growth being no doubt favored by the shade and accumulation of organic matter in the vicinity of the perennial plant. However, the brittlebush, *Encelia farinosa*, harbors no such growth, and in fact the region immediately surrounding an *Encelia* shrub is generally barren except in particular circumstances, which will be described later. In theory, the unpopularity of *Encelia* as a neighbor might be due to any one of a number of modes of interaction; but experiments show that, in fact, the nonassociation of annuals with *Encelia* is at least partly caused by a growth-inhibiting substance given off by *Encelia*'s leaves.

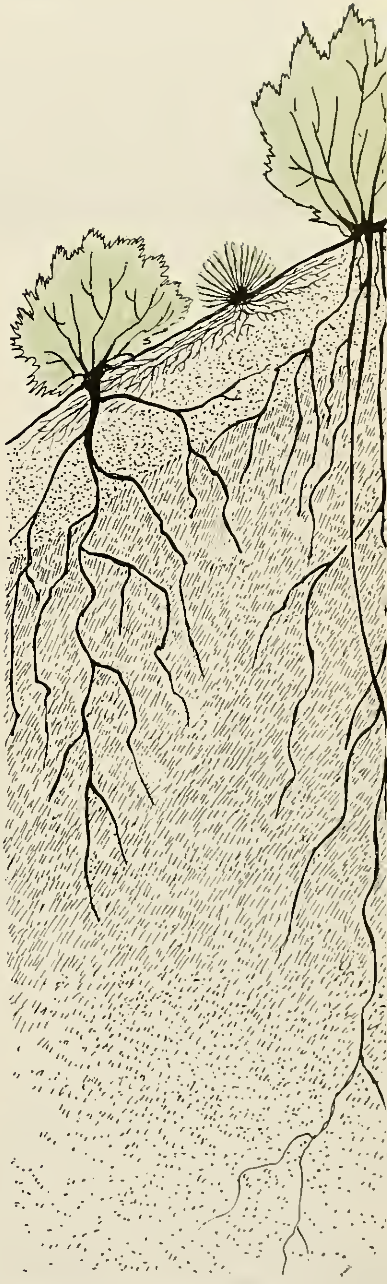
In preliminary experiments, the duff of fallen leaves was scraped up from the ground under *Encelia* plants growing in their native habitat. When the leaves were placed as a mulch over sand in pots containing tomatoes or other species, as little as ten grams of *Encelia* leaves per tomato culture were enough to cause a severe slowdown of growth, while larger amounts killed the plant outright. There is a certain selectivity in the action of *Encelia* leaves—*Encelia* itself, sunflower, and barley being but little affected, while other species are severely stunted in their growth or killed altogether, as was the tomato.

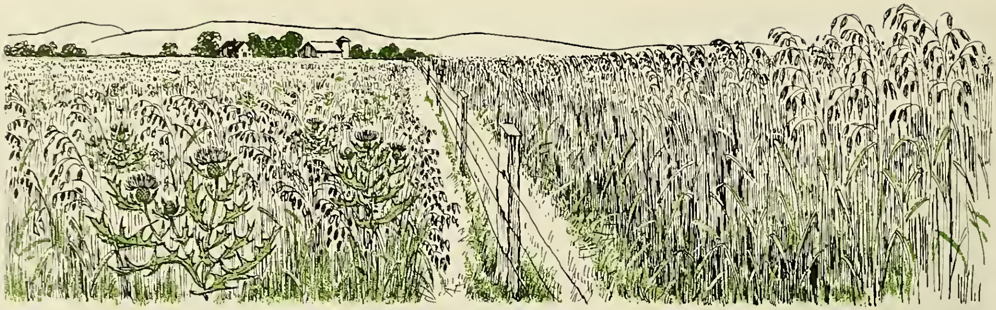
An active inhibitory material in *Encelia* leaves was isolated in crystalline form, and shown by Reed Gray and myself to be a previously unknown chemical substance, 3-acetyl-6-methoxybenzaldehyde. The material was also prepared synthetically, and the synthetic material found to have an activity identical with that of the native material—in both cases, half of the tomato seedlings' growth was inhibited by concentrations of approximately fifty milligrams per liter of nutrient.

These experiments, using fallen leaves as a mulch on cultures of tomato plants, also showed that the toxic material of *Encelia* leaves may be leached from the fallen leaves by water, and still other experiments have shown that the fallen leaves, under natural conditions in the desert, keep their toxicity in the absence of rain—and, in fact, that they can keep it until the next seasonal rain. Such fallen *Encelia* leaves, collected from under an *Encelia* bush and distributed on the open desert floor or under a shrub that normally welcomes and harbors neighbors, inhibit the growth of annuals just as does the *Encelia* shrub itself.

Thus, there seems to be no escaping the conclusion that, under natural conditions, the growth of any susceptible species would be inhibited by the toxic substance present in the fallen leaves about an *Encelia* plant, and that the lack of growth in annuals associated with *Encelia* under natural conditions is at least partly due to the production, by *Encelia*, of this toxic substance. The interesting exception, mentioned above, to this general rule occurs in certain mountainous areas, where *Encelia* grows on slopes subject to frequent torrential floods, which wash away the duff of fallen leaves from under the *Encelia* plant. In these regions, annual plants are often found in association with *Encelia*.

ONE of the most generally known and most widely discussed cases of possible chemical interaction among plants is that of the black walnut tree, *Juglans nigra*. This tree has a detrimental effect on neighboring plants of a variety of species, and since the area over which it exerts this effect coincides with the spread of the root system, competition for nutrients or water cannot be immediately discounted as its cause. But Everett Davis, working in West Virginia, has sought to identify the injurious effect of black walnut with the compound, juglone, found in parts of the tree both below and above ground. Davis has shown that juglone is, in fact, toxic to tomato and alfalfa; but he has not shown that it is released into the soil by the roots or other parts of the black walnut, or that the tree's injurious effect on other plants is due


ROOT SYSTEMS in California chaparral—*l. to r.*, whitethorn, yucca and scrub oak—show how competition may be reduced if roots explore different levels of soil.



INHIBITING EFFECT of thistles on oats is seen in adjacent fields: field at left is infested; the other, clear. A Swiss botanist of the last century, Augustin de Candolle, was first to suggest growth inhibition might be due to chemical cause.

specifically to juglone or any other toxic substance. In this case, we have at best a correlation between the occurrence of a toxic compound in the plant and growth inhibition of some sort that is carried out by the tree. It will be interesting to work out the physiological relations of the black walnut in further detail.

THE chemical interactions thus far discussed lead to conflict between individuals of different species, but chemical inhibitors may also cause conflict between individuals of the same species. Such an instance has been described in some detail by Arthur Galston and myself in the case of the composite shrub guayule, *Parthenium argentatum*. When this shrub is grown in sand culture, its roots give off to the nutrient medium a substance toxic to seedlings of the same species. We isolated the active principle in chemically pure form and showed it to be cinnamic acid, a normal constituent of the mature plant. This material inhibits the growth of seedlings of the same species with remarkable effectiveness, less than one part in 200,000 of soil sufficing to cause a significant depression of the seedlings' growth.

It is interesting, from an ecological point of view, that *Parthenium* seedlings are rarely found under a mature *Parthenium* plant—a behavior characteristic of a wide range of desert shrubs. Even when *Parthenium* seedlings are purposely transplanted into a sand culture of a mature guayule, they show poor survival and greatly reduced growth: a behavior that is, as experiment shows, directly related to the growth inhibitor produced by the roots of the mature plant, rather than to competition for light, water, or nutrients. While the ecological significance of this method of plant interaction is perhaps not great, because of the destruction of the inhibitor by soil bacteria, still it may contribute something to the normally wide spacing of individuals of the same species that is found not only with *Parthenium* but with other desert species as well.

A second instance of growth inhibition in individuals of a species by products of the same species has been revealed by the experiments of H. M. Benedict with the brome grass, *Bromus inermis*, in Wyoming. This grass, after it has grown on a site for a number of years, gradually enters a so-called sod-bound condition, in which the stand thins out and the plants die back. Benedict suspected that this sod-bound state might be due to the accumulation of a toxic substance or substances produced by brome grass roots, and he showed that, in fact, dried brome grass roots, even in small amounts, inhibit the growth of brome grass seedlings. This was demonstrated both in nutrient culture and in sand culture, by incorporating the dried roots into the sand or nutrient solution. In addition, leachings made from old brome grass cultures inhibited growth in younger cultures of the same species.

But while Benedict established the presence of a brome-inhibiting substance in brome roots, he did not extend his observations to the ecology of this grass under natural conditions, nor did he have an opportunity to identify the inhibitory principle involved. These remain interesting questions for further work.

Thus far, we have discussed some instances of actual or possible *conflict* between higher plants, based on particular, and more or less specifically growth-inhibiting, chemicals. While the number of illustrations might be further multiplied, the basic principle that such a mode of conflict can exist has been established.

Are there, now, instances of *cooperation* in plant societies based on chemical interaction? Such instances, while they may exist, have been but little studied and have quite possibly not been generally recognized for what they are. Perhaps the only case that can be pointed to with certainty as to its chemical nature is the interaction between legumes and associated nonlegumes, a case in which the nonlegume is benefited in its growth by something—possibly fixed nitrogen—produced by the leguminous partner in this plant association.

This phenomenon, although it had been suspected and even put to use in the field for many years, was first tested experimentally at Rutgers University by Lipman, who showed that in sand cultures low in fixed nitrogen, individual plants of the cereal grains may obtain nitrogen from a leguminous plant, such as a pea, grown in the same pot. It was subsequently established, through the work of Virtanen, in Finland, Roberts, in Wisconsin, and others, that the fixed nitrogen is excreted from the roots of these legumes as amino acids, which provide nitrogen in a form readily available, to other non-nitrogen-fixing species.

THE interaction between leguminous and nonleguminous plants is, then, nutritional and borders on the economic interaction that was mentioned at the start. In fact, we would expect beneficial *chemical* interaction between mature higher plants to be of limited importance generally, because these plants do not, as a rule, need or benefit from the presence of any organic substances they may find in the soil—they make their own food by the process of photosynthesis.

Seeds, on the other hand, cannot do this, and in many species, their germination *is* beneficially influenced by particular organic substances. Perhaps, then, plant co-operation and association are sometimes owing to the fact that one species produces germination-promoting substances that influence seeds of a second species. The observations that Frits Went made in the Javanese rain forest on the restriction of particular epiphytic species to particular host-tree species, might reflect some such relation between the host tree and the epiphytic seeds. In any case, it is evident that further investigation, carried out from a physiological point of view, will be necessary to establish how far chemical co-operation extends in higher plants.

We have seen, then, that the individual plant can interact upon its neighbors by at least one means in addition to "economic" competition for light, water, or nutrients. This additional means is provided by chemical substances produced by one individual that influence the development of others. Of the few instances in which this mode of interaction has been established, most consist of growth *inhibition* and are owing to substances that can, with considerable specificity, act on individuals of *other* particular species.

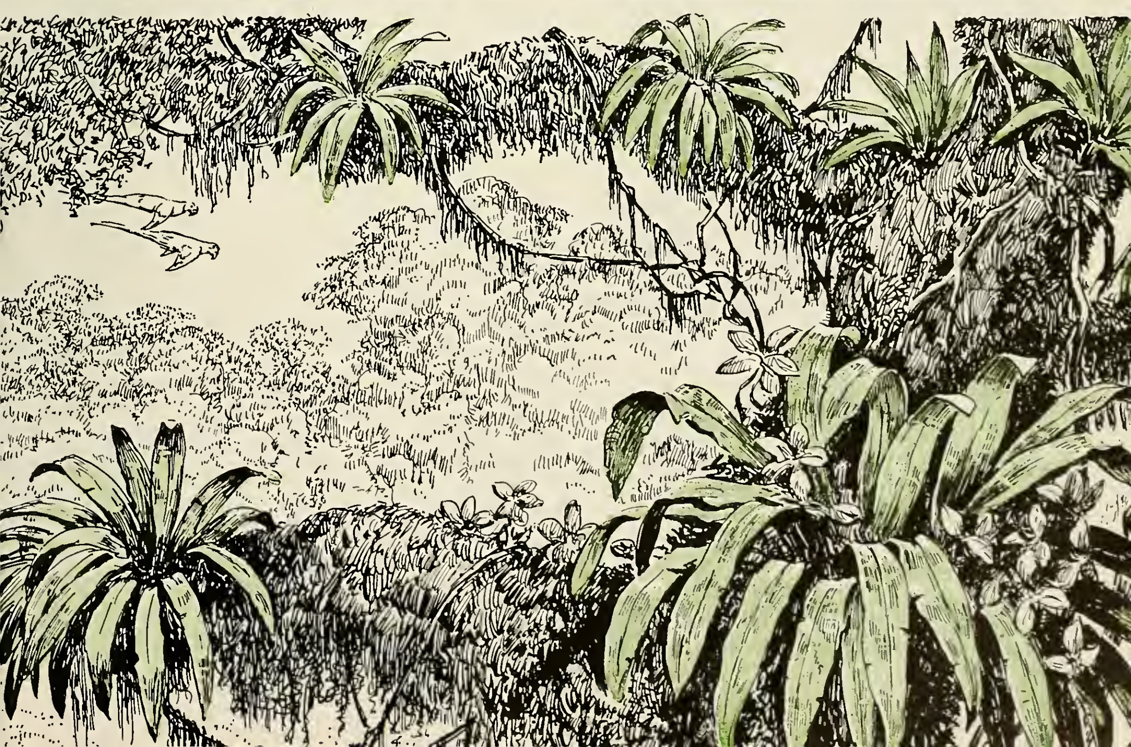
We should now ask how widespread this chemical interaction is, in the world of higher plants; and, even where chemical interaction occurs, what its quantitative importance is as compared to economic competition?

Chemical interaction by means of growth inhibitors would seem to be widespread, if we may judge from the number of instances in which such plant parts as leaves or roots yield extracts that greatly inhibit the growth of one or another second species. In a survey of the leaves of native woody species of one section of eastern California alone, half were found to contain principles toxic to the growth of one selected test plant, while half yielded extracts that were essentially nontoxic. Similar data have been summarized by several students.

However, the mere presence, in a particular plant, of substances that *can* inhibit the growth of other plants does not prove that the substance in question actually *is* responsible for any ecological effect. This must be shown in each instance and proved by experiments in the plant community itself, and the cases in which such final proof has been adduced are few. In the instances of chemical plant interaction that have been worked out in detail, the phenomenon was first noted because of its striking nature in the field.

In these instances, then, chemical plant interaction would appear to be an important, perhaps a dominant feature in the relations of plant to plant within the association, and additional cases in which the chemical aspect is of great weight will doubtless be uncovered. We do know, however, from the great mass of ecological investigations, that competition, the economic factor, is of the most general and pervasive importance in plant relations. In general, we must expect chemical plant interaction, where it is found, to constitute merely another factor superimposed on economic considerations—one factor of several that, together, determine the course of conflict or co-operation in plant society.

Chestnut species from Java, *Castanea argentea*, is among plants having particular association with specific kinds of epiphyte — plant growing on a host plant, but not parasitic. The host is thought chemically to benefit epiphyte's seeds.



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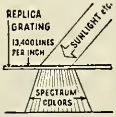

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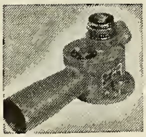

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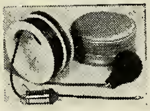

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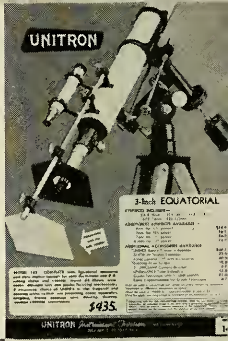

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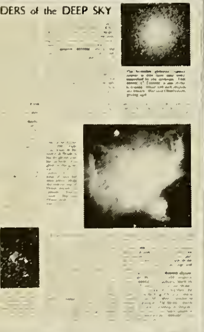
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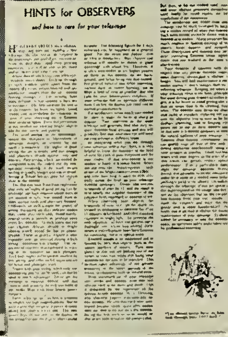
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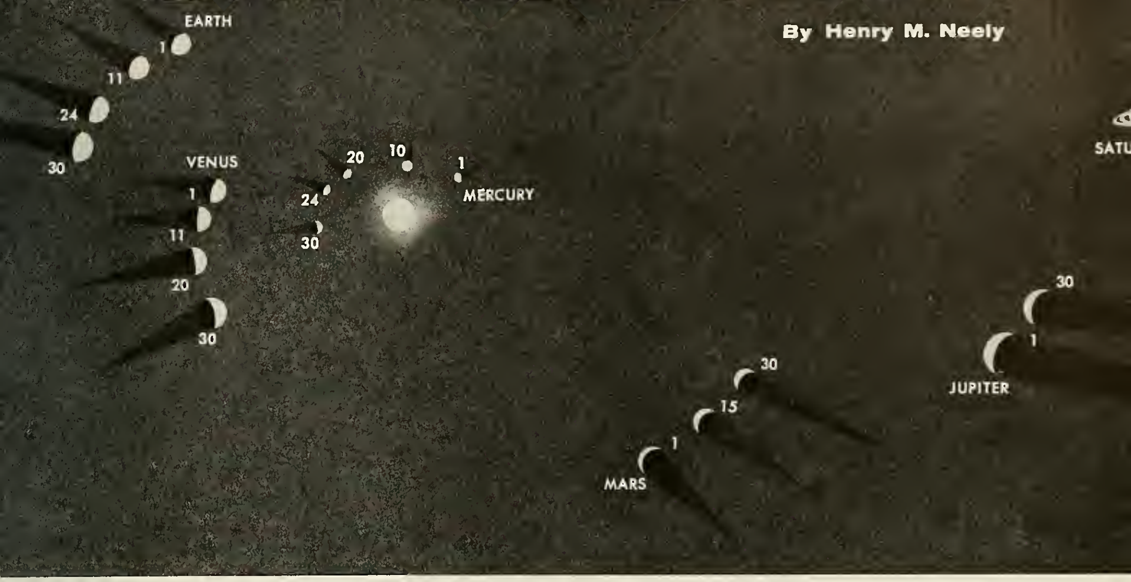
SKY REPORTER

By Henry M. Neely



IF WE COULD STAND in a space station an enormous distance above the sun, we could look down, this month, and see the principal planets (including, of course, the earth) in approximately the positions shown in the drawing, *above*. No attempt has been made here to indicate in correct scale the relative sizes or distances, but the planets' directions from the sun and from each other are accurate enough to illustrate the reasons for some of the changing pictures an observer on earth will see in the November sky.

Customarily, we have shown the positions of the earth, Venus and Mercury for every ten days. This month, however, they are shown for November 11 instead of the tenth and for November 24 instead of the twentieth, for these two dates mark important positions in the cases of Venus and Mercury.

On November 11, Venus, as it is seen from the earth, will appear to be at the greatest distance from the sun that it will reach this month—the so-called "greatest western elongation." It will then be a brilliant object in the southeastern sky as dawn begins (see lower drawing, page 518).

On November 24, Mercury will be in "inferior conjunction," which means that—viewed from our hypothetical space station above the sun—earth, Mercury, and the sun will seem to be "joined together" by a straight line, with Mercury between earth and sun. In such a position, the little planet would be entirely lost in the sun's glare so far as watchers on earth are concerned.

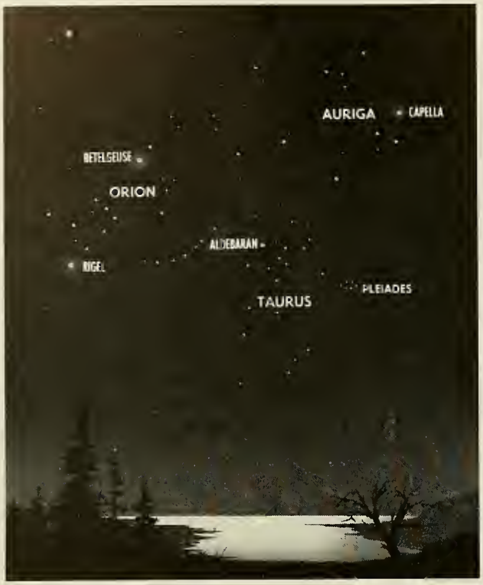
If we had given the positions of Mars and the earth for October 30, they, too, would have been in conjunction; but since Mars is farther from the sun than is the earth, this conjunction can never be called "inferior": Mars cannot come between sun and earth. Also, if the diagram had been carried forward for another week, it would have shown Jupiter in conjunction December 5. In other words, the earth—speeding much faster than Jupiter—will move around to bring the sun between earth and planet. Jupiter will then be lost in the glare of the sun.

The picture does show that, for the first ten days of the month, an observer on earth would be able to see Jupiter a little distance away from the sun. The earth's speed however, constantly reduces that distance. The result, for viewers on earth, is that, in the southwest, Jupiter is seen setting progressively earlier in the evening as darkness comes on; but by mid-month, it will be gone before the twilight sky provides a dark background.

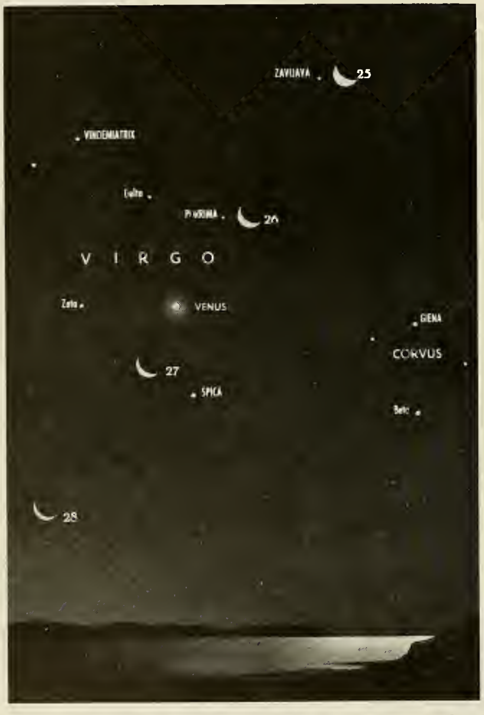
SATURN, however, can still be seen fairly clear of the sun, but that distance, too, is constantly decreasing because of the earth's greater speed. Saturn will be setting at about the time for using the roll-around map. It will be found, on the map, very low over the horizon in the southwest.

Just as Venus is seen at greatest western elongation on November 11, Mercury will be at greatest *eastern* elongation on November 3. In the case of Mercury, however, this is a most unfavorable elongation for northerners. The reason for this is that Mercury does not revolve around the sun in the same plane as the earth. Sometimes the little planet can be 7° above that plane or, at the opposite point in its orbit, 7° below. When its course is elongated above our plane, we in the Northern Hemisphere have the best chance to see it. On November 3, on the other hand, Mercury is at maximum distance below our plane, and observers in the Southern Hemisphere will have a better chance than we will to see it; hence, it is not shown here.

At the times for using this month's map, the sky is a source of endless fascination for observers who own small telescopes or binoculars, or even ordinary opera glasses. This is because the richest part of our Milky Way is in



MAXIMUM for meteors known as Taurids is from November 8 to 12. Taurus is shown here as it appears after moon has set.



VENUS, Spica, and old moon's crescent are shown in close proximity just before dawn on November 26 and 27. On the 11, Venus, seen from earth, is at greatest western elongation.

ideal position for leisurely "sweeping." The luminous band now starts at the horizon between northeast and east, sweeps up over the north until its is almost overhead and arches down to the horizon between west and southwest. Innumerable fields rich in countless thousands of distant stars, invisible to the naked eye, will be revealed by any instrument of even the most modest power.

As a matter of fact, Milky Way sweeping is one activity in which high power is a disadvantage. The greater the magnification, the smaller the field of view; but the dramatic effectiveness of these star-strewn fields is strengthened by seeing great multitudes thickly sprinkled over a large area. Large area requires low power.

An hour or more can enjoyably be spent starting in the northeast just above brilliant Capella, and meandering slowly up past the fields that border Perseus, through the riches that surround the whole constellation of Cassiopeia, then through Lacerta overhead to the twin branches of the Milky Way that fill virtually the whole area of Cygnus and the long side of the Summer Triangle, and finally go down over the southwest horizon.

Lovers may consider the moon romantic, but moonlight is the enemy of the Milky Way explorer. So—at map times—there will be too much moon from November 5 to about November 15. After the mid-month full moon, conditions in the early evenings will be more favorable.

FOLLOWING, in calendar form, are the events of interest to sky watchers this month:

All month: At the times for using the roll-around map, newcomers to star identification can get an early introduction to the parade of the most brilliant stars that move across the sky at Christmas time.

Roll the map to bring the east horizon to the bottom. Just over the horizon is Taurus, along with the famous star cluster, the Pleiades, whose rising always heralds the coming of the winter stars. The map for the Taurid meteors on this page shows these stars well up in the sky, as they will be seen just before dawn.

November 2 to 23: A good many years ago, these were important dates for observers of meteor showers. The Andromedes (or Andromedids), seeming to come from the constellation of Andromeda, were among the most dependable elements in such phenomena. Then the Andromedes disappeared, and it was believed that the swarm's orbit had been changed by a close approach of Jupiter. Lately, however, there have been a number of reports indicating that they may be reappearing, and they will be anxiously looked for this month. The moon will not interfere with observation until about the eleventh or twelfth, but observing must be done before 3:00 A.M., at which time Andromeda will be about one-third of the way up the sky between west and northwest; after that, the radiant point will sink too low to be seen clearly.

November 8-9: Go out at map time and face south. Below the moon, not far above the horizon, will be the southernmost star of the first magnitude that can be seen from our mid-latitudes. This is Fomalhaut (pronounced fome-al-ought) in the little constellation Piscis Austrinus, or Southern Fish. The star's name means "The Fish's Mouth" because of its position in the imagined figure of the Southern Fish.

November 8 to 12: These are the best dates for watching the "shooting stars" known as the Taurids. Maximum is November 10 and on that date, the moon sets about 2:00 A.M., so its light will not interfere at the best times for viewing—4:00 to 5:00 A.M.—upper drawing, *left*.

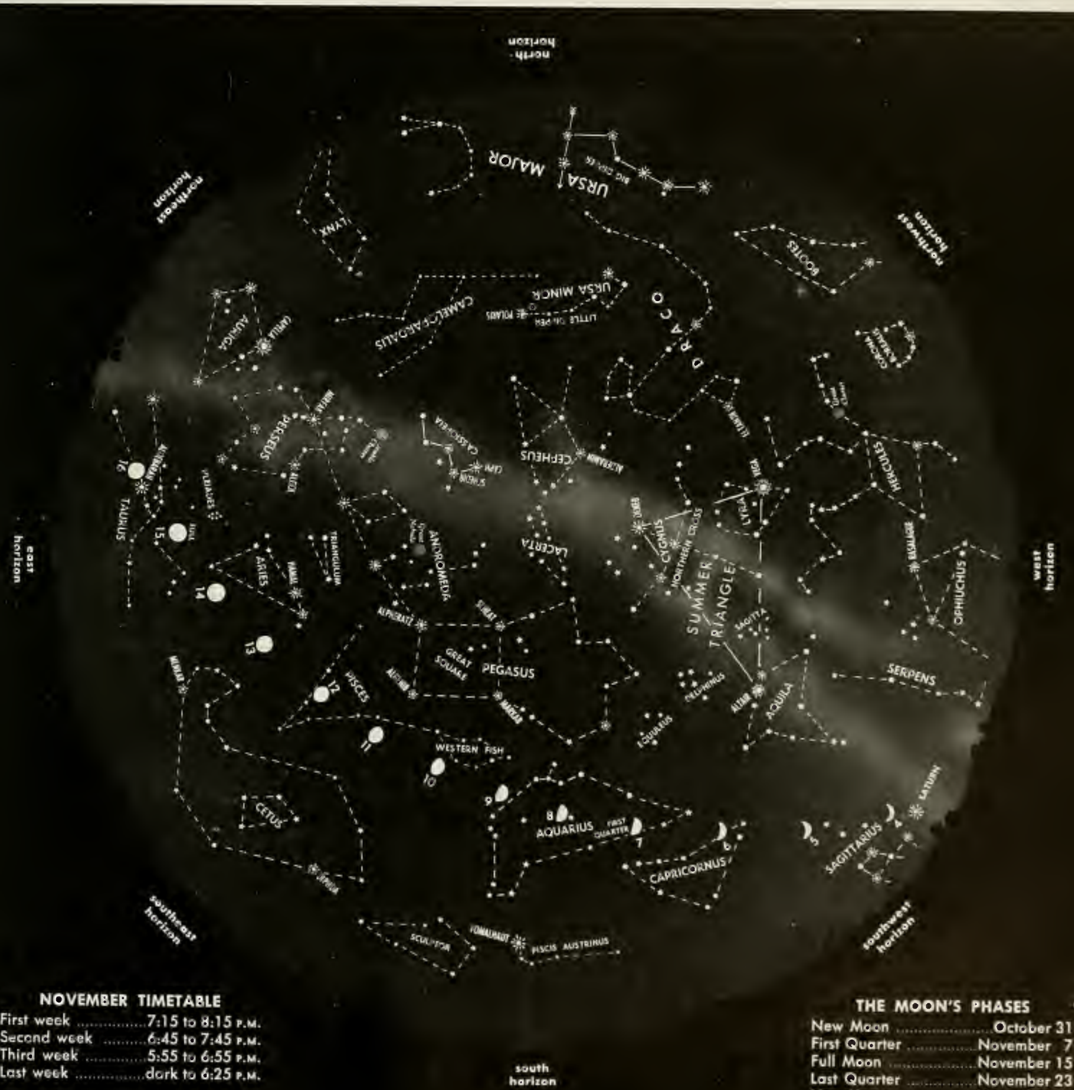
November 10 to 12: The bright moon, about midway between first quarter and full, will introduce the beginner to the famous Great Square of Pegasus. If you face southeast (see roll-around map), the Great Square will be directly above the moon. The dimmer stars will be blotted out by the moonlight, but the four that form the Great Square can be seen.

November 11: This is the best night this month to watch the whole eclipse of the bright star Algol in Perseus. Every two days, twenty hours, and forty-nine and one-tenth minutes, Algol fades more than one magnitude. Fading takes about five hours, minimum lasts about twenty minutes, and in another five hours Algol is back to normal. Minimum tonight is about 11:30, so the whole process can be watched by enthusiasts ready to make a night of it.

November 10 to 20: Meteors known as the Leonids are due to appear, with maximum on the 14, 15, and 16 of November. Just before dawn, Leo will be very high over the southeast. The moon is full on fifteenth, but it will be setting in the northwest as dawn begins. The watcher for the Leonids will therefore have his back to it, and it should not interfere with his observing.

November 26-27: Early risers should look at Venus, the thin, old moon and bright Spica in the east as dawn begins. See lower map, *left*.

MR. NEELY, editor of *Sky Reporter* since 1947, now prepares this regular feature for NATURAL HISTORY.


north horizon
northeast horizon
northwest horizon
east horizon
west horizon
southeast horizon
southwest horizon
south horizon
URSA MAJOR
BIG DIPPER
LYNX
BOOTES
CAMELOPARDALIS
URSA MINOR
LITTLE DIPPER
POLARIS
DRACO
CORONA BOREALIS
AURIGA
CAPELLA
PERSEUS
ALGOL
MIRFAK
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ALDEBARAN
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LACERTA
DENEB
CYGNUS
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VEGA
LYRA
SUMMER TRIANGLE
OPHIUCHUS
ALPHERATZ
SCHEAT
GREAT SQUARE
PEGASUS
ALGENIB
MARKAB
PISCES
WESTERN FISH
SAGITTA
DELPHINUS
ALTAIR
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DIPHDA
AQUARIUS
FIRST QUARTER
CAPRICORNUS
SAGITTARIUS
SATURN
SCULPTOR
FOMALHAUT
PISCIS AUSTRINUS
16
15
14
13
12
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4

NOVEMBER TIMETABLE

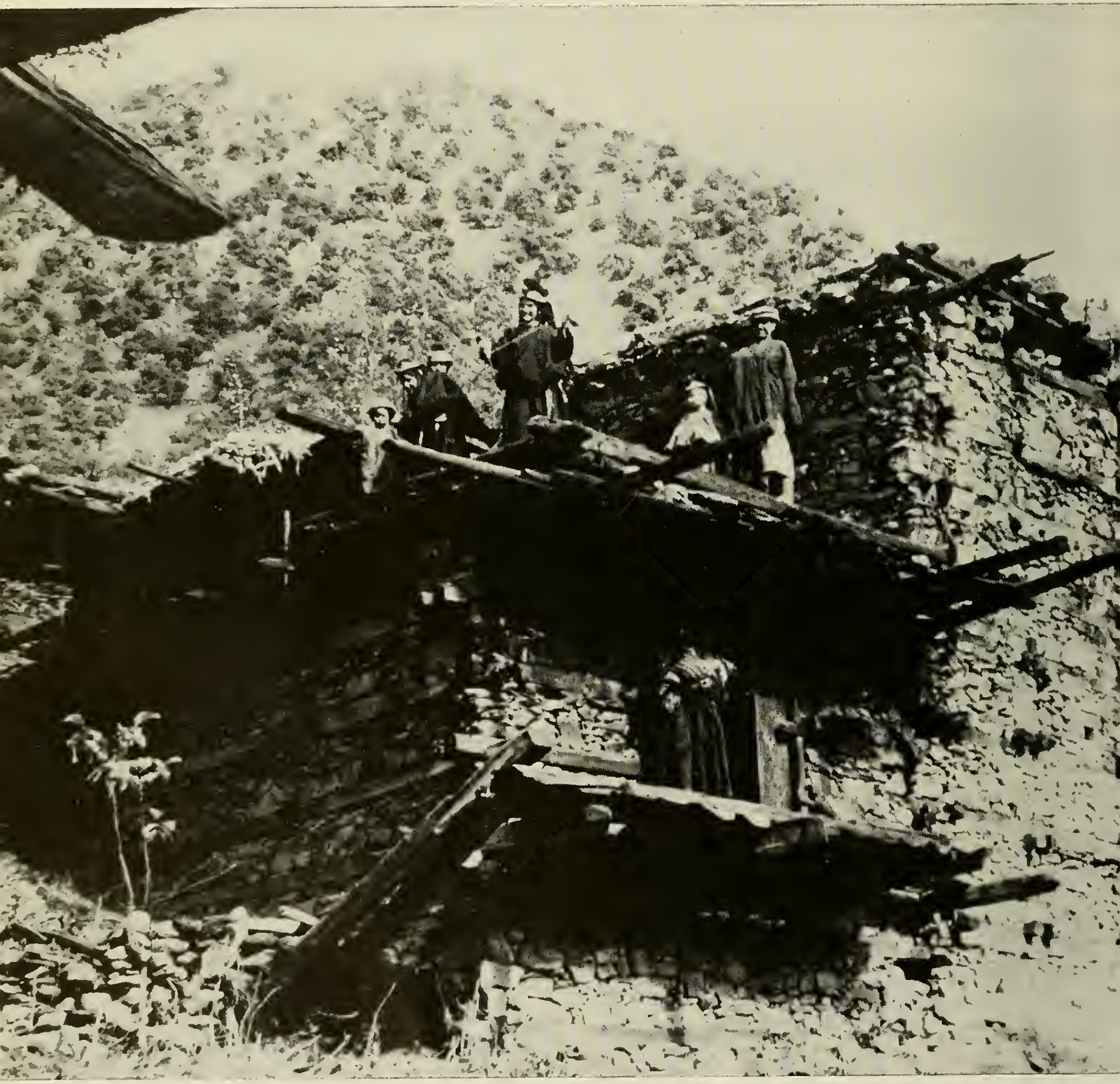
First week	7:15 to 8:15 P.M.
Second week	6:45 to 7:45 P.M.
Third week	5:55 to 6:55 P.M.
Last week	dark to 6:25 P.M.

THE MOON'S PHASES

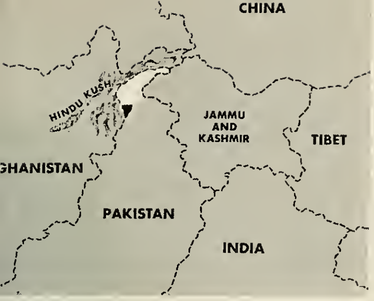
New Moon	October 31
First Quarter	November 7
Full Moon	November 15
Last Quarter	November 23
New Moon	November 30

LAST PAGANS OF THE HINDU KUSH

By Peter Snoy



Kalash-Kafir villages are built on rugged valley slopes in the Hindu Kush, one of main mountain systems in Central Asia (map, *above*). Made of stone, mortar, and wooden beams, the homes are built one below the other, and give

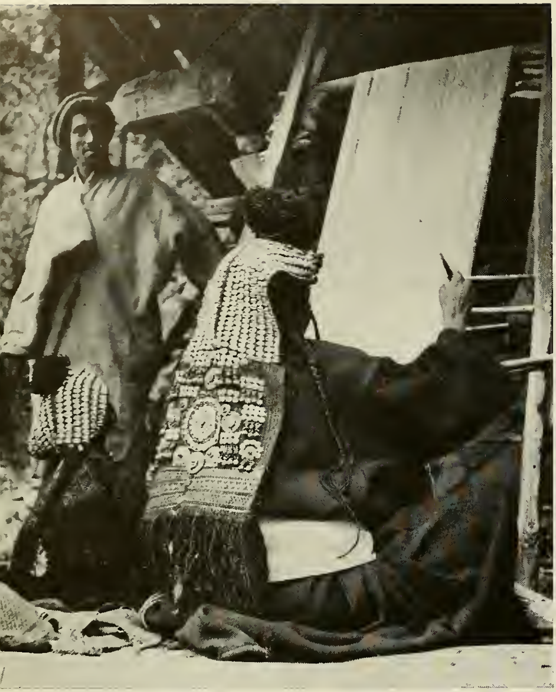


the impression of a flight of steps leading to the floor of the irrigated valley.

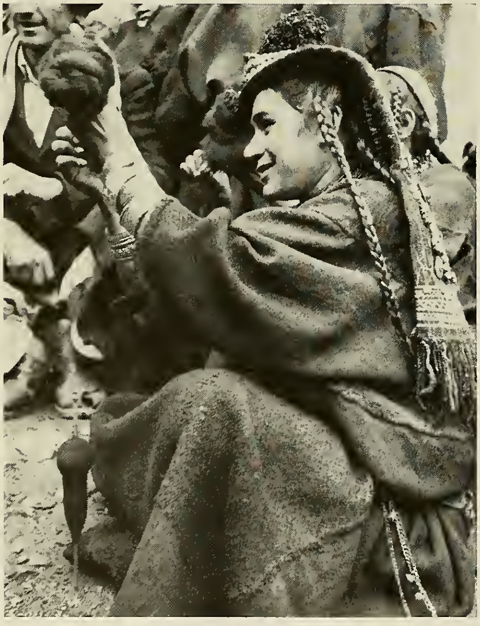
Ram's head decorates wooden door of this Jestak-Han, a special house where Kalash-Kafir clans observe those rites attendant on birth, marriage, and death.

When the British marched to Kabul, the capital of Afghanistan, in 1839, a delegation of tall, stately men—with blond or reddish hair and blue eyes—came to them from the valleys of the Hindu Kush. Known to the local Moslems as "Kafir"—the Arabic word for "unbeliever"—they had come, they said, to greet their "brothers." Although the British command had problems more pressing than the welcoming of these rather ragged brothers, whose very language was unintelligible to them, this incident was the first close contact between Europeans and the mountain people of the Hindu Kush. Protected by the inaccessibility of this savage mountain range and by their readiness to fight for their freedom, several small tribes of Kafirs had kept their own ancient culture alive for centuries, although girt by fanatical Moslems.

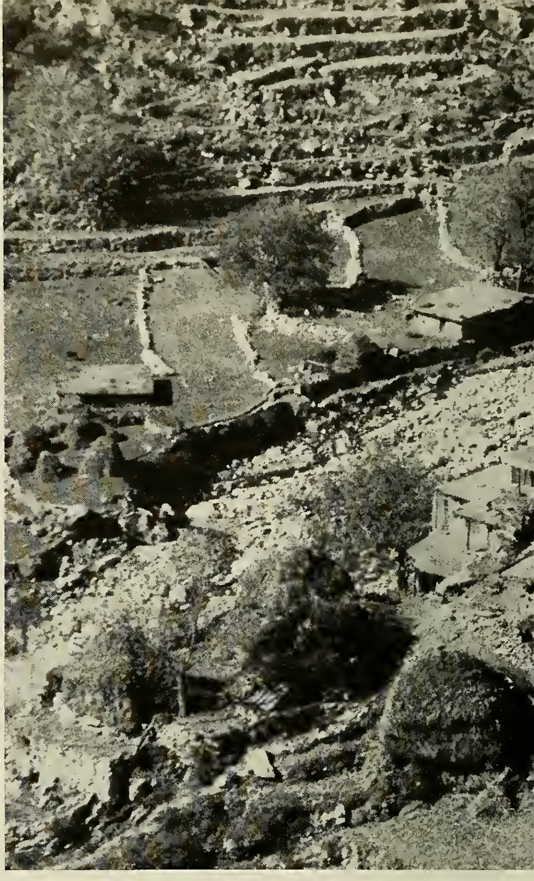
For a long time, the sum of knowledge about these Kafirs was scanty. But the fact that they regarded themselves as brothers to the Europeans, together with their physical appearance, gave rise to the speculation that the Kafirs were descendants of the Greeks who had entered the region with the forces of Alexander the Great (336-323 B.C.). Fortunately for history, an English physician, Sir George Robertson, traveled all alone through the homeland of these wild and mur-



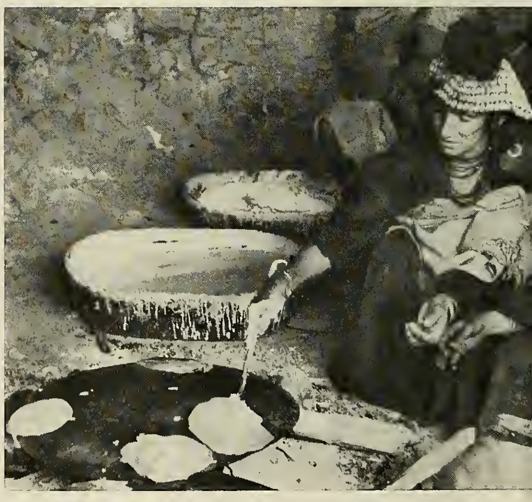
Shell-decorated headdress, or *kupass,* is worn by woman at loom, *above.* Women wear dark clothes, men lighter colors.



Comely young woman, *above,* with traditional long braids, uses a wooden spindle for making thread from hair of goats.

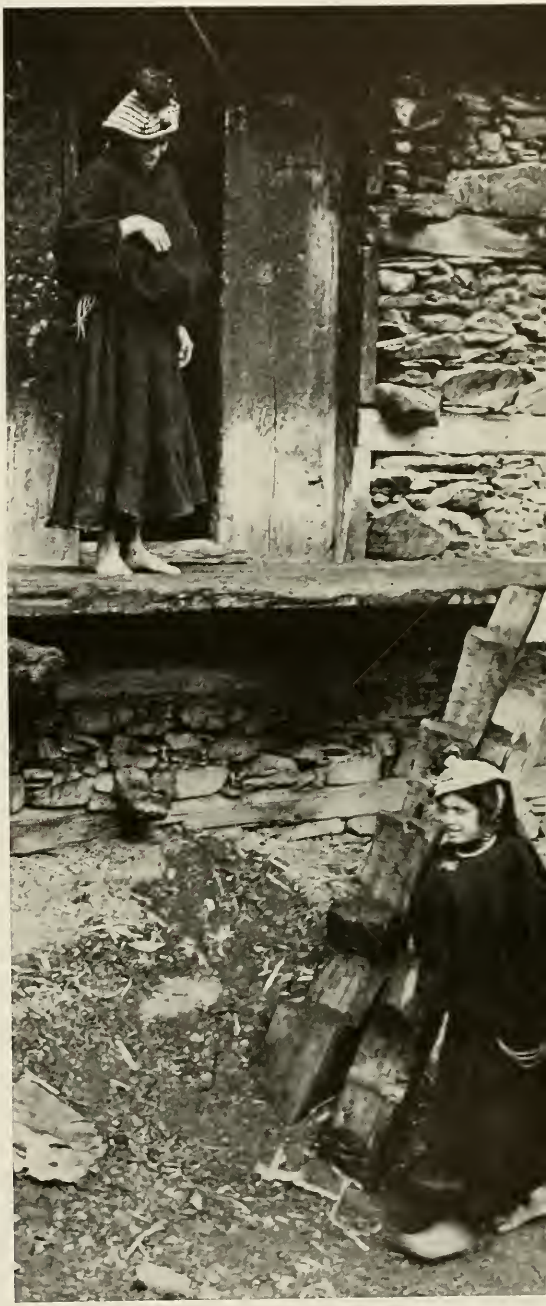


Kalash building sites were originally chosen with an eye to defense. Across this valley, which has an elevation of

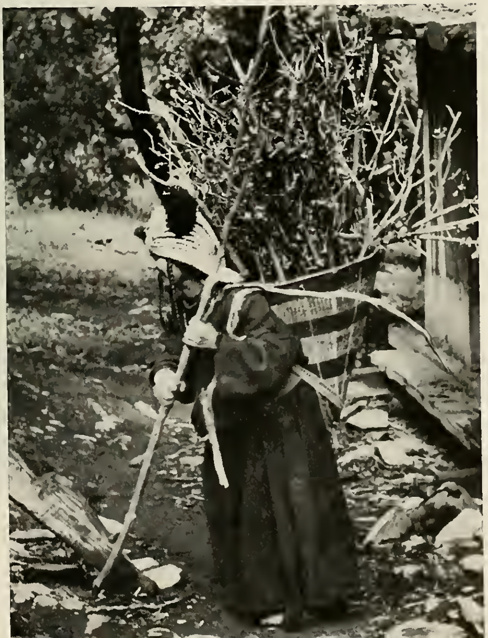


Bread dough, made of flour and water, is scooped up in the hand, *above,* then poured out on hot metal plate for baking.

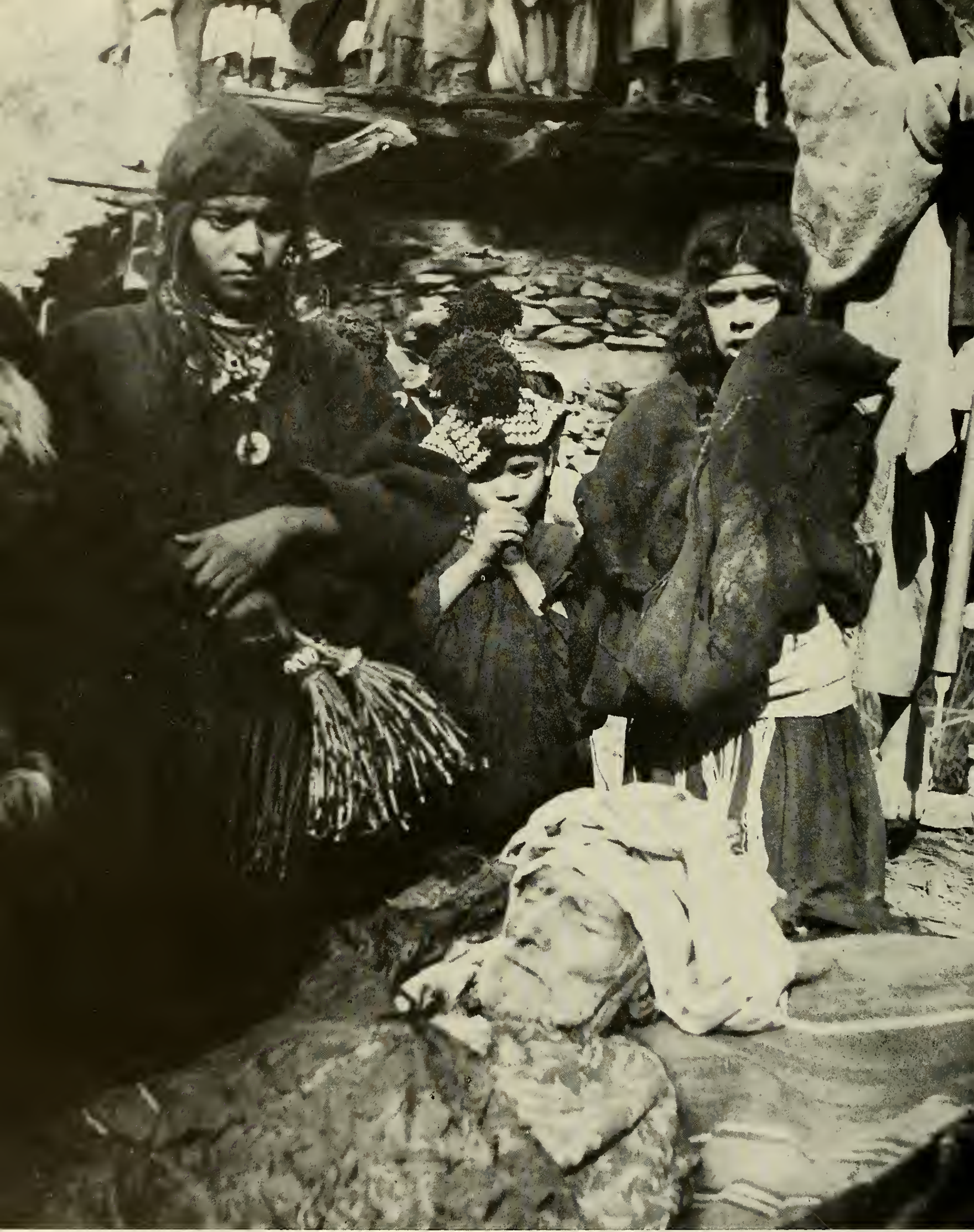
about 7,000 feet, can be seen the terraced fields in which tribesmen raise various crops. Fruit trees are also grown.



Ladder of notched logs is only means of access to porch of house, *above*, so sharp is the declivity of the mountain.



Conical basket holds kindling Kalash woman has gathered, *left*. In this society, the women do most of the manual labor.



FUNERAL CEREMONY for elderly Kalash includes use of fly switch, held by woman. Made of straw, braided with beads, shells, and feathers, it is believed to frighten away evil spirits. During ceremony women relatives discard headdress.

derous mountain people late in the nineteenth century, exploring the nearly impassable regions. His journeys proved to be the last chance for a study of the culture of the Kafirs. A few years later, the Afghan king Abdur Rahman invaded the territory with his forces. It was winter, and the Kafirs, confined in their snowbound villages, fell prey to the king's whim. He subjugated them cruelly, and forced them to join the faith of Islam. The culture of the Kafirs, one of the oldest in Central Asia, was doomed. Today, this region is officially known as Nuristan, "Land of Light," and the former unbelievers are "Nuristani."

In the east, Nuristan borders on the kingdom of Chitral, which today is a part of Pakistan. There, close by the Afghanistan border, a small tribe—the Kalash-Kafirs, numbering fewer than 2,000 people—still lives according to its ancient traditions. The rulers of Chitral, although Moslem, have never showed any particular interest in proselytizing this small group to Islam; in fact, the Kalash-Kafirs have constituted a useful sort of buffer state between Chitral and its mighty neighbor, Afghanistan, to the west.

Today, the culture of the Kalash-Kafirs has much in common with the vanished Kafir culture of Nuristan. The Kalash, however, is a separate tribe with its own culture. There is a marked language difference. The Nuristani still speak so-called Kafir tongues—which form a special branch of the Indo-European family of languages. The tongue of the Kalash-Kafirs belongs to the Dard languages of India. Alas for romance, Greek traces remain neither with the Nuristani nor with the Kalash, which seems to rule out a Greek origin for these tribes.

Three inaccessible valleys in southwest Chitral—Rumbur, Bumboret, and Birir, by name—are inhabited by the Kalash-Kafirs, whose dwellings lie at an average altitude of five thousand feet. This region lies within the monsoon belt, and torrential spring rains make possible the dense forests that mark the landscape. In the lower sections, their stone, or evergreen, oak (*Quercus ilex*) predominates. Keeping its leaves both summer and winter, this tree is often the only source of nourishment for the Kalash flocks of goats and sheep. The great importance of the stone oak in the economy of the Kalash is celebrated in their ceremonial system. Whenever an animal is slaughtered, a twig of the stone oak must be dipped in its blood. At higher altitudes, conifers such as cedar, pine, fir, and larch provide the Kalash with resinous kindling and matchwood. The juniper, found at extreme altitudes, also plays a special part in the ceremonies of the Kalash. It grows in the alpine pastures where the herds are driven each summer.

The Kalash stress the importance of animal husbandry, the goat being their most venerated domestic animal. Herding, like hunting and warfare, is exclusively a man's occupation. The Kalash villages lie mostly in good positions for defense—on the steep slopes of deeply serrated valleys. The flat-roofed houses are built of boulders and loamy mortar, with interposed wooden beams. They form compact villages that look like a flight of steps descending the declivity. Toward the bottom of the valley lie artificially irrigated, terraced fields in which are grown wheat, barley, millet, legumes, and, more recently, maize. Fruits are also grown — apricots, mulberries, and grapes. In contrast to the Nuristani, who leave all agricultural work to the women, Kalash men plow, sow, and do the threshing themselves—another considerable difference between the two related cultures.

The isolation of the valleys that the Kalash inhabit is sharply reflected in their religious beliefs. The Kalash acknowledge one superior deity, the creator of the world and of man. But certain local deities, the "Dewa-log," are much more important for their daily life. And in different valleys the Kalash-Kafir honor different Dewa-log. In Kalash myth, these are described as individual personalities, each with his own strengths and weaknesses. Occasionally, one will outwit another—reminding us of the contests among the Greek and the Scandinavian gods. It may be this trait in myth that prompted the theory of a Greek origin for these people. But it is clear that the gods of the Kalash are linked to the old Indian pantheon. Thus Mahandeo, the mightiest of the Dewa-log, recalls the name of the Hindu god, Shiva-Mahandeva. Varin, in turn, resembles the Indian deity, Varuna, not only in name but also in his function as the guardian of truth and right, and the punisher of evil.

For the Dewa-log, the Kafirs erected small buildings at certain places, said to have been chosen in ancient times by the gods themselves. Each is named as the house of an individual god. An elaborately carved board — with an opening for gifts, such as the blood of sacrificial animals, flour, wine, grapes, and small pieces of bread—forms a wall separating the world of man and the world of the gods. As a rule, four carved horses' heads tower above this board.

Such a "god-house" belongs to the realm of everything that is considered holy and pure. Reality for the Kafirs is divided into two realms, the holy and the profane. They consider as impure everything connected with the birth and death of man. What concerns gods and certain spirits is considered pure or holy. Woman, the bearer of children, belongs in the impure realm. During menstruation or confinement, a woman may not stay in the village. A special house, which a man may never enter, stands outside the village, away from every road. Since a woman is obviously unclean, she may never approach these god-houses, and is subject to many restrictions. For instance, she may not eat honey, for bees are considered holy, nor may she approach a goat, since the goat is especially venerated. For this reason, the goat sheds are outside the village. A married man who comes into contact with the unclean world must undergo purification. He may not, after marital relations, enter a goat shed unwashed. Nor can married men perform the sacrifices to the gods: the greatest of ritual cleanliness is necessary for this, and only virgin youths qualify. They alone are permitted to perform the sacrifices in the god-houses: they alone may milk the goats. Sexual purity is the high ideal of young Kalash boys. By contrast, the virginity of girls is not deemed important.

The burial yard, where the dead are placed in wooden caskets that lie on top of the earth, also belongs in the unclean category. The Kalash avoid entering a cemetery: the spirits of the

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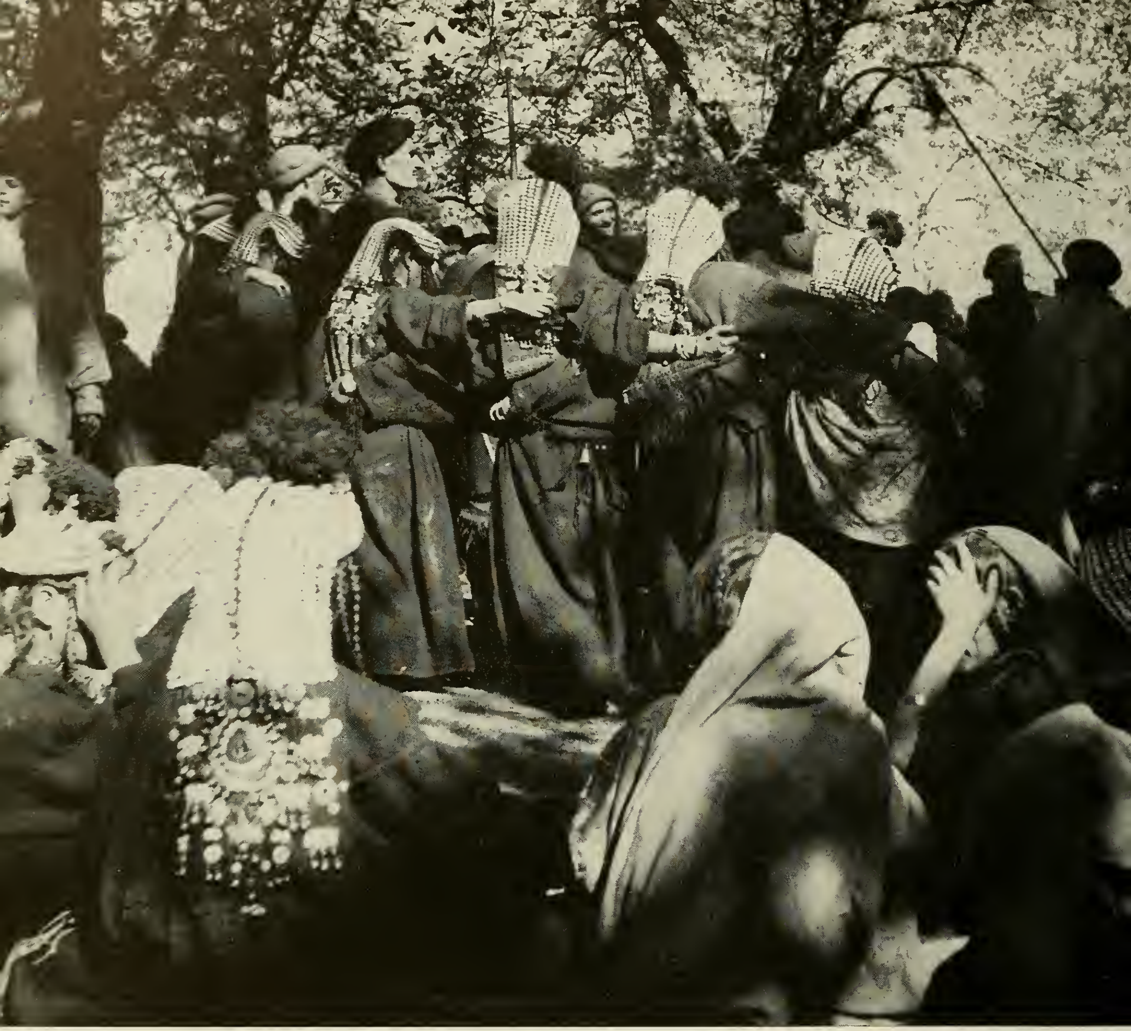
Peter Snoy, an ethnologist, lived with the Kalash-Kafir tribes for seven months while a member of the German Hindu Kush expedition of 1955-56. Photographs are work of Hans von Meiss-Teuffen and his wife, who are daring explorers and world travelers.



Mourners perform ritual dance during funeral ceremony. Shawled women in foreground are members of the family. Corpse will lie on bier for three days and, during this period, all who visit the house of mourning will be fed. The

dead are feared. On the other hand, there is a decided worship for the dead—a sort of ancestor cult, in which those who have acquired merit during their lives are singled out for attention.

This acquisition of merit is a cultural link between the Kalash and the Nuristani. According to Dr. Robertson's descriptions, such so-called ceremonies of merit were far more highly developed in the Nuristan of the past than among the present Kalash.

Today, a host who organizes a series of feasts, during which the village community or the whole tribe is feted, can ascend to a corresponding position of social esteem. Wealth is the prerequisite for such feasts, but often a man spends his entire fortune in order to gain social standing. Wealth, as such, is not honored: only a man who distributes his wealth gains social prestige and may be elected into the council of the elders.

If a Kalash man dies who has acquired merit in this way, or who has distinguished himself as a brave warrior or hunter, his funeral ceremony —which, even for an ordinary man, means feeding the entire clan — becomes a still more costly affair.

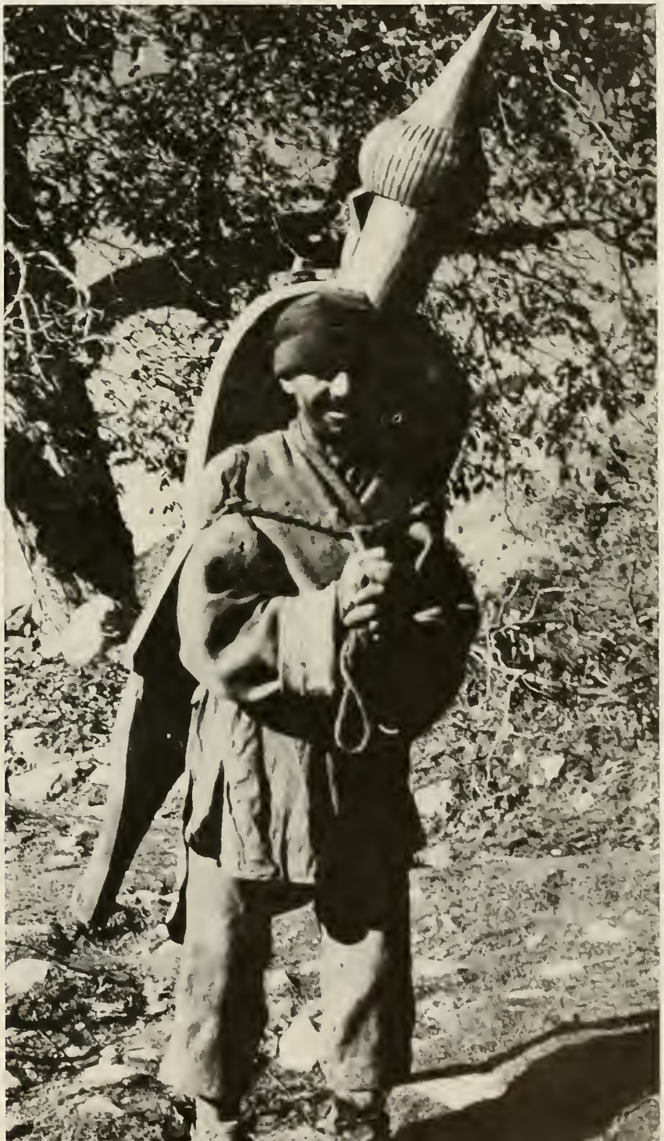
The corpse lies on a bier for three days before it is taken to the cemetery. During this period, everyone who comes to the house of mourning is fed. One year later, provided the deceased has a claim to merit, a wooden statue—representative of the social standing of the deceased—is erected in the cemetery. The dead man is portrayed either standing or on horseback. Naturally, a substantial feast is also involved, so that the erection of such a statue is a very expensive undertaking. But the dead man's descendants do everything they can to honor an ancestor who has acquired merit.

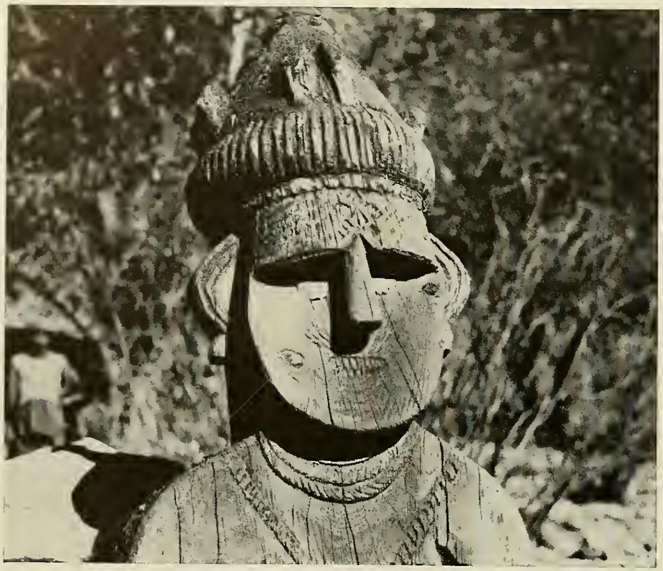
Kalash practice a variety of ancestor worship, emphasizing the men of merit.

One of the various kinds of spirits that populate the world of the Kalash and bring them luck or disaster is known by the Persian word *Parian*. These are female spirits that seem to correspond most closely to the fairies of European folklore. They live high in the mountains and are the shepherdesses of the wild goat species —the ibex and the markhor. These animals are kept as the fairies' domestic herds, and are guarded, milked, and even slaughtered. Hunters have a special relationship with the *Parian*. According to Kalash belief, the *Parian* put the purified bones of a slaughtered markhor back into its skin, and restore the animal to life with a shake. If the *Parian* are favorably inclined toward a hunter, they will send such animals his way, as easy game.

An exceptionally powerful being, almost a goddess among the *Parian*, is Jestak. In ancient times, according to tradition, when man and spirits and animals still lived together in harmony, Jestak taught man how to sacrifice a goat so that a little blood of the slaughtered animal would always be sprinkled on a twig of stone oak. Jestak is, above all, the protectress of the family and house. Each clan, which comprises seven patrilineal generations, has its own clan house, called the "Jestak-Han." The sacred object of Jestak—a carved board with horses' or rams' heads—is found here. The Jestak-Han is distinguished from ordinary houses by the ornate carvings on the entrance door and on the wooden pillars that support

Woodcarver carries a funerary figure to cemetery. Despite their regard for ancestors, Kalash fear spirits of dead, and avoid entering burial grounds.





Head detail of a figure in a Kalash cemetery. Note necklace, decorations on robe collar and on hat. All of these are indications of rank of deceased.

Statues of the dead lean casually on caskets that lie on top of the ground

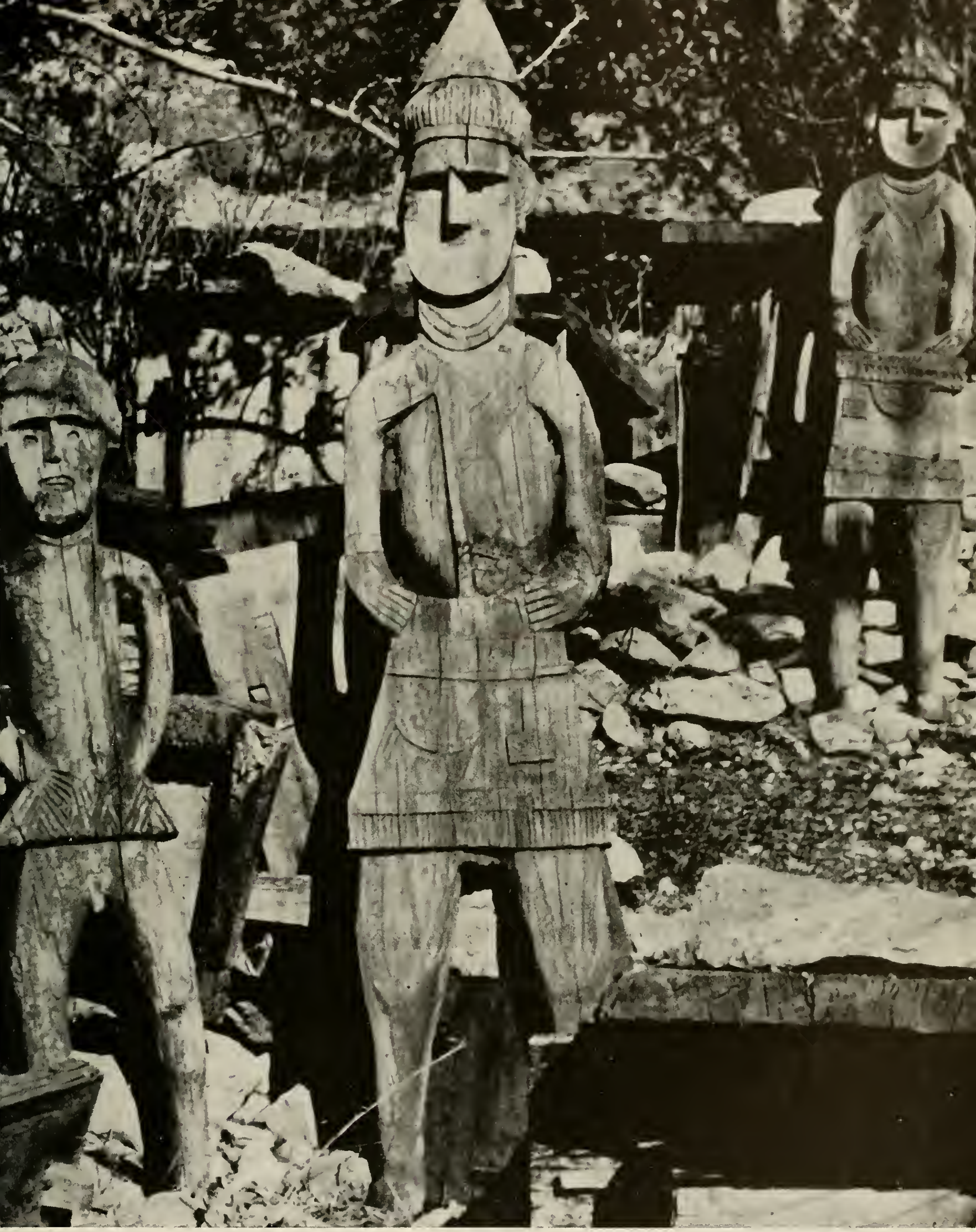
the flat roof. Various ceremonies connected with the life of the clan take place here: newborn babies are accepted, weddings are celebrated, and the dead are laid in state.

During their big winter festival, one of a series that takes place during the course of a year, the Kalash observe several ceremonies in the Jestak-Han. The winter festival lasts fifteen days. It is a fertility feast, the climax of which occurs on the night of the winter solstice. Every year, a bisexual god is believed to visit the valley of Bumboret, and bring blessings to the Kalash for the coming year. Numerous goat sacrifices, for which the Kalash congregate by torchlight beneath a tree sacred to the god, and a vigorous combat between a "pure" and an "impure" person, are the two main events of the night. During the days preceding the solstice, individual clans assemble—each in its own Jestak-Han.

On one day, a feast for the ancestors is piled up in front of the house at twilight, while the whole clan congregates inside. A fire is lighted outside, and an old man calls the ancestors with a loud voice so they may come and taste the food. Quickly, the door is shut, and in breathless silence everyone waits to hear what will happen. The flickering fire casts ghostly shadows on the walls of the Jestak-Han: the spirits of the dead have arrived. When the fire has burned down, the feast food is carried back inside and the clan begins a merry celebration.

On another day, soot drawings are made on the walls and posts of the Jestak-Han, mostly representations of domestic goats, ibex, and markhor. At dawn the following day, an effigy of a markhor, made of bread, is set up in the Jestak-Han, to be shot at with bows and arrows by the boys of the clan. If it is hit, a great clamor starts in the village: "We're driving out the wild animals!" These Kalash customs are believed to be a guarantee that the goats will prosper.

Of special interest is the important position of the goat in Kalash society. Archeological studies show that the goat was among the first of the gregarious animals to have become domesticated, and the most ancient traces of domesticated goats have been found in what is now Persia and Afghanistan. This region is also the home of the race of wild goats that is considered to be the ancestor of all domestic breeds. It is not surprising that at the border of this region still lives a tribe in whose most ancient customs, beliefs, and way of life the wild and domesticated goat plays such an important role.



in Kalash cemeteries. Each is erected a year after a man's death if, by the distribution of his wealth, he had won claim to special merit. Dead are shown either standing or on horseback, while the details of figure show his status.

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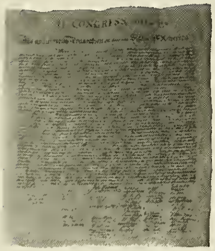

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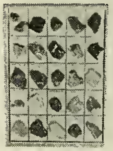

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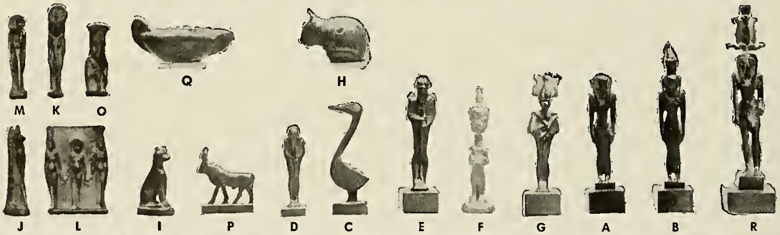

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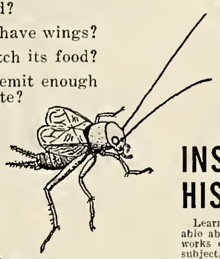

ANSWERS 1. No, only the black spots. 2. The darkling beetle. 3. At least 17 years. 4. Almost 100% efficient (the ordinary light bulb is only 10% efficient). 5. Yes. 6. Because they eat through lead cables, causing short circuits. 7. No, they have been found as many as 1200 miles at sea. 8. No, only every sixth generation. 9. The Tichoptera. 10. Most varieties of butterflies.

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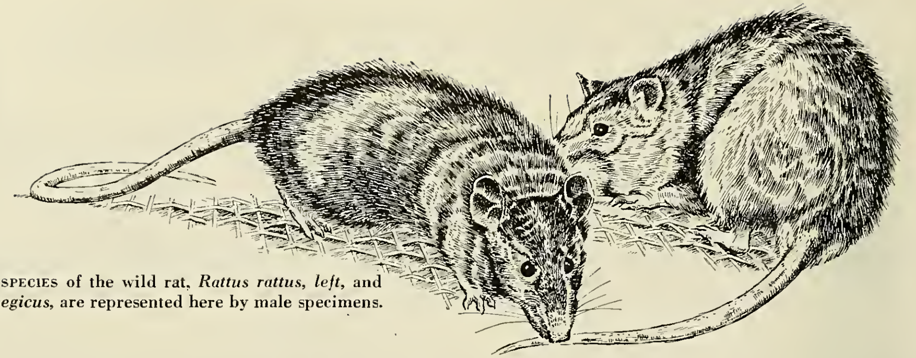


TWO MAIN SPECIES of the wild rat, *Rattus rattus, left,* and *Rattus norvegicus,* are represented here by male specimens.

THE WILD RAT

This animal's behavior has given it a reputation for cleverness

By ANTHONY BARNETT

AN AMERICAN FARMER, according to Sir James Fraser in *The Golden Bough,* wrote a polite letter to his rats, to say crops were short, and he could not afford to keep rats during the winter: he had been very kind to them, but for their own good they should go to some of his neighbors who had more grain. "This document he pinned to a post in his barn for the rats to read." The farmer was in good company in treating wild rats as human, or more than human. Five hundred years ago, the Bishop of Autun, in France, put rats under a formal curse; and there are plenty of other examples of resorting to magic, charms, prayers, and curses in the hope that thereby rats would be driven away or killed. Even some twentieth-century biologists, usually rather blasé about the capabilities of species other than their own, have been impressed by *Rattus norvegicus:* one referred to attempts to exterminate rats as "a veritable battle of wits," and still another has described rats as "diabolically clever animals."

Certainly, whether clever or not, rats are found in almost every human community, and in some they probably outnumber the human population. They undoubtedly do so in many laboratories, but in laboratories, as a rule, they belong to one or more of the tame varieties and most typically they are white, although they still belong to the species *R. norvegicus* (also known as *Mus decumanus*). These domesticated creatures have been so much used in so many kinds of research that the psychologist N. L. Munn has written a vast and valuable volume entitled *Handbook of Psychological Research on the Rat,* in which wild rats are hardly mentioned. Munn's treatise contains, inadvertently, a curious comment on the studies of rat behavior: it is in a chapter oddly entitled "Abnormal and Social Behavior," and is to the effect that little research has been done on social behavior in rats because ". . . rats are not especially influenced by each others' actions." In what follows, I hope to show that the Bishop of Autun and his followers, the believers in the intellectual powers of rats *and* Dr. Munn are all mistaken. The Bishop and the rest overestimate the murine status, Dr. Munn underestimates it.

There are two species of rats of world-wide importance. The so-called "black," "roof," or "Alexandrine" rats *(Rattus rattus)* range from black to tawny with a pale belly. This was the plague rat of the Middle Ages in Europe. The other species (already mentioned) is the common brown rat, often called the Norway rat for no good reason; it is sometimes black, even in the wild state. Unlike *R. rattus,* which is a climbing species, *R. norvegicus* is a burrower. All laboratory rats are of this species, although they seldom get the opportunity to burrow. Matings between wild and white are fully fertile; the offspring are all wild-type, but *their* offspring come in a variety of colors. *R. norvegicus* can, and does, carry plague, too.

There are other species of economic importance in the East and in Australia. They have been serious pests of sugar plantations, and in Java a small species upset Europeans by nesting inside their bamboo furniture.

APART from "cleverness," two things are likely to impress the casual observer of rats. One is their catholic choice of foods; the other is their capacity for multiplying. Rats will eat anything that men will, and some things we refuse. Apart from house mice, few animals are so versatile. The study of the feeding behavior of rats has been put on a rigorous basis during the past fifteen years or so, and has shown that their success owes much to a very delicate system of checks and balances, which had not been suspected by naturalists lacking a technique of controlled experiment.

To make this clear, we must first

A member of the zoology department at Glasgow University, in Scotland, ANTHONY BARNETT is also author of *The Human Species,* a biology of man.

consider the exploratory behavior of rats. As everyone knows, if wild rats are disturbed in a familiar environment, they at once take to cover. But, if wild rats are released into an *unfamiliar* area, their response, despite the disturbance, is likely to be exploration. Even if they enter a place of concealment, they soon emerge to sniff about further.

The motivation behind such exploratory behavior is so powerful that it may have priority over both fear and hunger. Hungry laboratory rats will ignore food until they have investigated a new environment. The opportunity to explore can, indeed, be used as a "reward" in a learning experiment: if a rat is repeatedly put in a situation in which it can take one of two pathways, and if one path leads to a dead end, but the other to a larger area, then the rat tends to learn to go to the latter, just as it would learn to go to food or water. An important difference, however, is that a rat learns to go to food or water only if it is hungry or thirsty, that is, suitably deprived; while exploration can be evoked without first imprisoning the animal in any way.

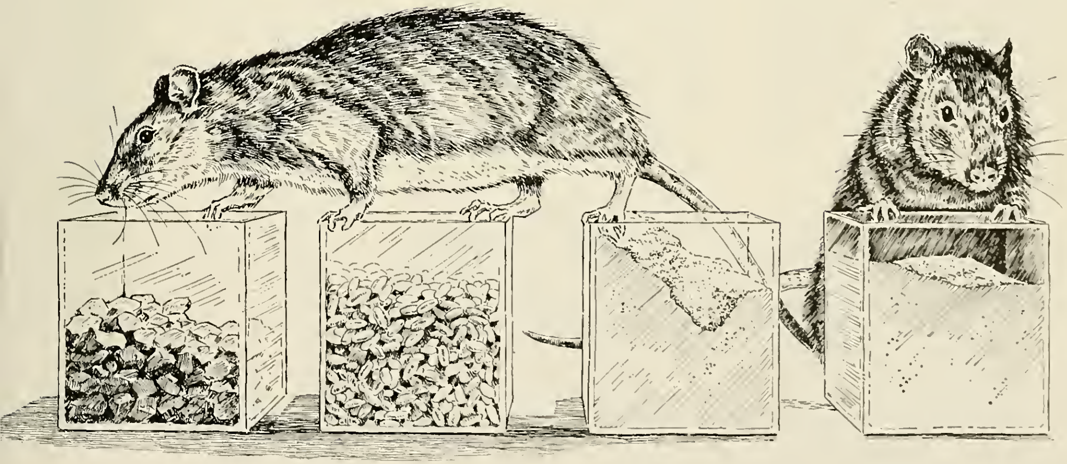
What exactly makes a rat go exploring? Ingenious experiments on laboratory rats have shown that this behavior is closely analogous to what we call curiosity in ourselves, and that rats often behave as if they wished to avoid boredom. The *effect* of the behavior is that it puts them in as wide a variety of situations as they can reach. In the wild state, there is no doubt that, within a certain area around the nest, every accessible point is regularly investigated; other things being equal, the more recently a place has been investigated, the less likely it is to be revisited.

Rats do not confine themselves to topographical exploration: they sniff, taste, and sample everything potable or edible they encounter. Here, too, the "boredom effect" is evident; if a variety of foods is available, all will at least be nibbled; and when a quantity of one has been eaten, the rat is likely to move over and take a second and third course off the alternatives.

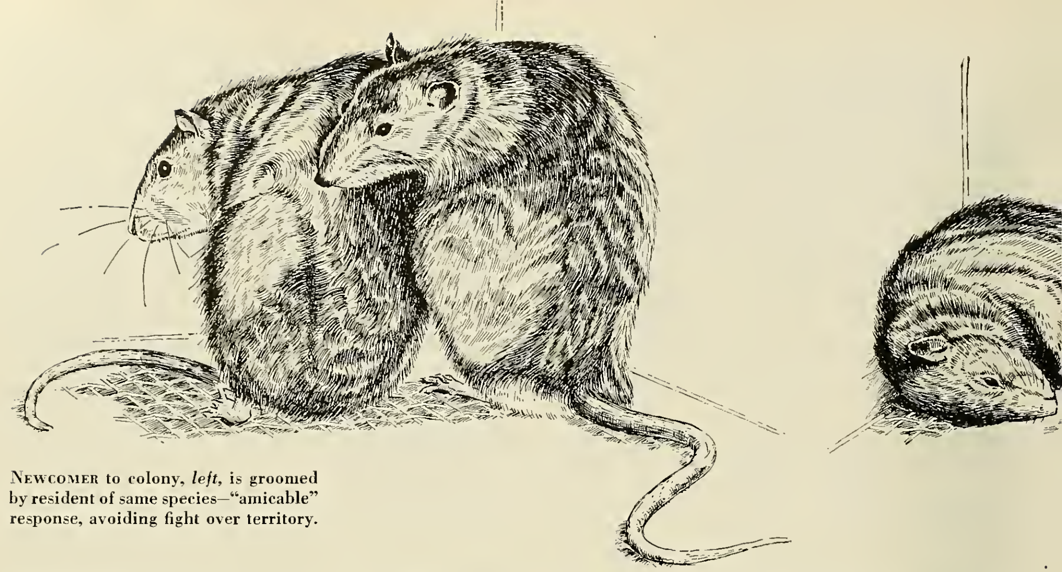
This behavior is an essential element in the feeding behavior of rats. Just as general exploration gives the rat experience of every feature of the environment, so sampling of food informs it what sorts of nourishment are available. Through this sampling, a rat learns not only where food can be found, but also—in some instances—what the nutritional value of the food is. This ability to choose the better of two alternative foods has been very fully studied in laboratory rats. Of course, like most animals, they adjust the total amount of food eaten to their energy needs; but they do more than this. If they are made salt-deficient, and are offered a choice between plain and salty water, they choose the latter, even though before the deficiency existed they would have drunk the plain water. The same sort of effect has been observed with some, though not all, vitamins.

The picture so far presented is of insatiably restless, "inquisitive" animals, always poking their noses into something, especially something new, and sampling everything they can get hold of. This is true for laboratory rats, but if it applied also to wild rats they would be quite unable to survive the most casual efforts of men to poison them. Yet, in fact, they are decidedly difficult to eliminate by poisoning — and still more difficult to get rid of by other means. This is due to another feature of their behavior, one which is opposite to their exploratory activity and, so to speak, protects them from it. Wild, but not laboratory, rats tend to *avoid anything new* if it is encountered in a familiar environment. This superficially simple fact accounts not only for much of the difficulty we have in ridding ourselves of rats, but also for the widespread belief in their wiliness.

This behavior was first clearly described during the Second World War, at Oxford, England, as a result of research on the problems of protecting food stocks from pests. Wild rats in a settled colony develop regular habits of movement: they use fixed paths between nest or cover and food and, although they also explore elsewhere, one can be confident that they will use



Investigating food, two rats sniff liver, wheat, flour and sugar. Rats' feeding behavior is part of this animal's great curiosity: rats will sample everything they encounter, but have ability to choose the most nutritious of several foods.



Newcomer to colony, *left*, is groomed by resident of same species—"amicable" response, avoiding fight over territory.

these paths each night. However, if an object—however harmless—is placed on such a path, the result may be a complete avoidance of that part of the home range. The avoidance may last only a few hours or it may go on for days. If the object is food, eventually it will be approached and sampled, at first only in the smallest quantities. What happens after this depends on the physiological effects, and the flavor, of the food. If both are satisfactory, the food will be eaten. If, however, the food contains poison, the ill effect may have time to make itself felt before a second sample is taken. In this case all feeding stops for a time, and *eating the food comes to be associated with illness.* This sequence of events has undoubtedly been responsible for a great many failures to kill rats by poison baiting. Repeatedly putting down the same poison bait merely makes things worse, since learning to avoid the bait is then regularly "reinforced."

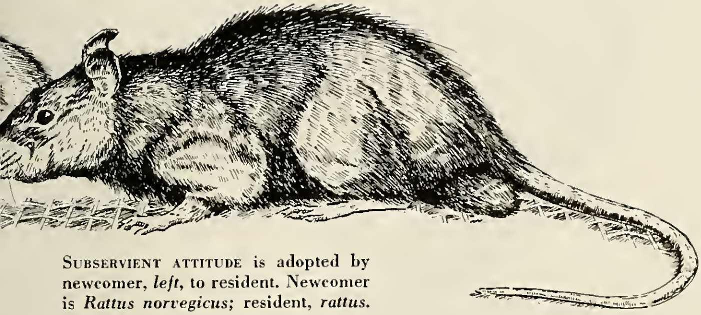
Poison shyness is, in fact, another aspect of an ability we have already mentioned—to choose the more nutritious of two foods. This, in practice, turns out to be an extraordinarily efficient protection against poisoning. It might be thought, for example, that if the poison were very highly toxic this would overcome the difficulty of coping with the initial, tentative sampling. But when this was tested with sodium fluoroacetate, which is several times more toxic than strychnine, it was found that some rat populations developed poison shyness to baits containing it. Yet this poison was so dangerous to man (several children have been killed by it) that it was clearly at or beyond the level of toxicity acceptable for general use.

During and after the War, this difficulty was solved in Britain and many other countries by the method of "prebaiting"—a technique we owe to the Oxford ecologists already mentioned. The rats are first trained to accept bait by distributing only a harmless mixture. After a few days, during which the rats may even come to adjust their movements to the visits of those laying the bait, poison is added and is then, as a rule, readily eaten by the animals.

This is a good example of a fairly simple technique developed from matter-of-fact, careful observation of what a pest actually does in typical environments. A short account, however, is inevitably oversimplified, and cannot do justice to the scale or difficulties of the research required. Also, we must add that there is a substantial objection to prebaiting — one which may account for the fact that it was never generally adopted in North America. It is a prolonged job, and it is difficult to train a lot of low-salaried people to do it properly. (Fortunately, there is now a way of getting round the need for prebaiting.)

In most of the scientific studies of poisoning rats, much stress has been laid on the importance of killing a large proportion of the total population. The reason for this has been especially clearly shown by workers in Baltimore. Consider how a population grows. If it starts with a small number, perhaps only with a litter of six from a single pregnant female, its growth is slow at first. However, if the environment is favorable, numbers increase geometrically, and there comes a stage of exceedingly rapid growth. This is sooner or later checked: the rate of increase declines until a maximum is reached; and this maximum is then maintained, provided the environment remains constant. Something like this "ideal" demographic sequence has been actually observed in a number of rat populations.

Slowing the increase in numbers and reaching a stable plateau depend on the action of controlling influences, which act with increasing force as population density increases. Such factors can include predation by dogs, cats, hawks, and men; a shortage of undisturbed nesting places; a shortage of food; and conflict among the rats themselves. The most important implication of all this, for practical purposes, is that it is futile to kill, say, around half a rat population by poisoning or trapping: the result of doing so is that the survivors then have greatly improved conditions (owing to the reduced competition for food and nests), and so breed much more rapidly; the population is thus soon re-



Subservient attitude is adopted by newcomer, *left*, to resident. Newcomer is *Rattus norvegicus;* resident, *rattus.*

stored to its original numbers—as has been directly observed, in Baltimore and other places.

The aim, therefore, must be either to kill a very high proportion of the total number, or to alter the environment so that it will not support so many rats. The latter has a more lasting effect, but is often far more difficult to achieve; it can rarely be accomplished quickly.

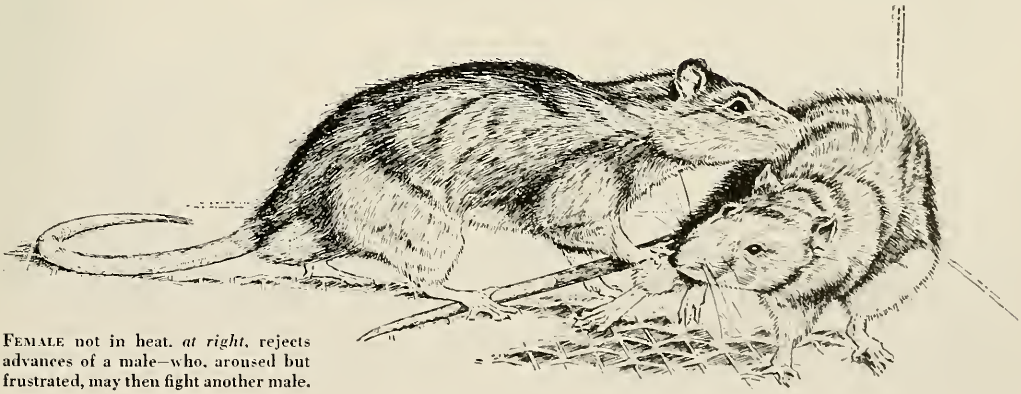
If a human community does succeed in reducing the shelter and other amenities available for rats, its efforts are substantially aided by the rats themselves. This is because in certain circumstances rats fight each other, with a consequent increase in the death rate and decrease in fertility of those "defeated." The exact conditions of this fighting have been studied in experimental colonies of wild rats kept in large cages. The rats included both species we mentioned; they were either trapped as adults in the docks of Glasgow, Scotland, or were descendants of rats so trapped.

Two early experiments helped to clarify the sort of questions that would arise from a study of rat societies. In one, a number of males were put together in a cage; all were strangers to one another, and none had previously experienced the cage. They settled down, grew well, (rats grow throughout life) kept excellent health and slept together in groups in the nest boxes. This observation was especially surprising because of the twelve rats present, six were *R. norvegicus* and six *R. rattus,* and the rivalry between these two species has long been known. In the other experiment, six males and six females, all *R. norvegicus,* formed the colony. After a few weeks, only one male remained — the largest; the females were still in excellent shape, and some were pregnant. Later, other comparable experiments gave results similar to those two.

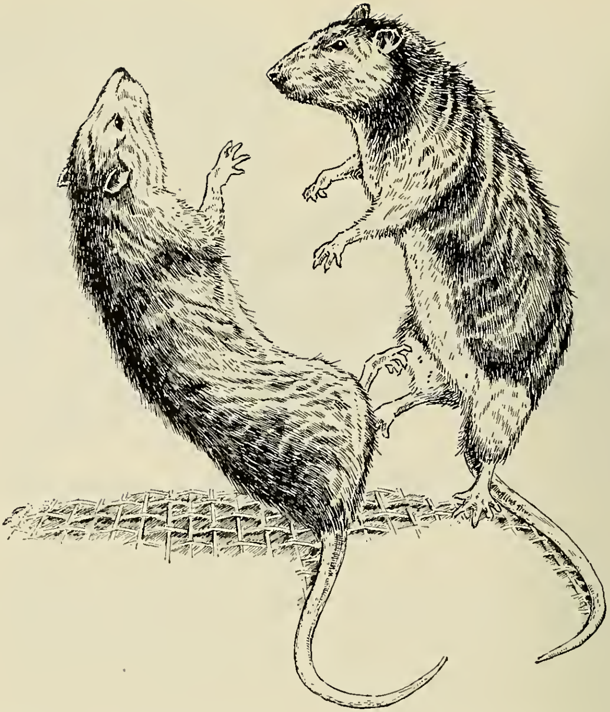
An obvious question to ask, then, is: What are the causes of fighting among rats? But observation showed that it was equally profitable to ask: Are there features in the behavior of rats which tend to *prevent* fighting? We often think of rats as very combative creatures and ignore the fact that they can live in large thriving colonies, so we must ask a third question: What makes rats assemble?

Close observation and filming of rats in artificial colonies showed that wild rats, like tame ones, are intimately gregarious. They not only huddle together while asleep or resting, but they have a system of actions that promotes close contact. The most distinctive of these acts consists of crawling under the belly of another rat; it is seen especially among males in situations that might lead to conflict—as in the encounter of strangers described below. Rats deliberately walk over each other, too—an act that has nothing in common with one human being trampling on another; this is seen most often in peaceful conditions. Rats also groom each other: that is, they nibble gently another's fur. This, like crawling under, is prominent in situations of conflict, but is not confined to them.

These activities all come in the category of "social signals," of the type



Female not in heat, *at right,* rejects advances of a male—who, aroused but frustrated, may then fight another male.



BOXING RATS, both of *norvegicus* type, are drawn here. The newcomer, *on left,* seems to be getting worst of the fight.

which tend to prevent conflict and to encourage herd behavior. Undoubtedly, odors are other "social signals," though these are difficult to study. A female is recognized by a male as being in heat as a consequence of glandular secretions with a typical odor. It has been shown, in fact, that laboratory rats can recognize a receptive female by odor alone. Wild rats of both sexes leave odor trails as they move about their living space. Where they regularly run in contact with light-colored surfaces, they leave clear evidence of their passage in the form of a dark smear, and such trails are followed by other rats.

THE conditions in which sociability breaks down and fighting breaks out are quite narrowly limited; and they can be defined with some precision from observations of rats kept in artificial cages and enclosures. If one wishes to establish a stable, healthy colony of wild rats in artificial conditions, the best method is to begin with a group of sexually immature individuals. They need not be litter mates. Alternatively, a colony may be started with a single adult male and several females. In either case conflict is exceedingly unlikely.

By contrast, there is one type of situation in which fighting is highly probable. This is when an adult male enters a region in which another adult male is already established. In one series of experiments twenty males were introduced into established colonies: all were attacked, and eighteen died. The addition of females rarely resulted in injury or death; and of young, never. Male *R. norvegicus*, when already settled in a cage, did, however, attack *R. rattus* of both sexes.

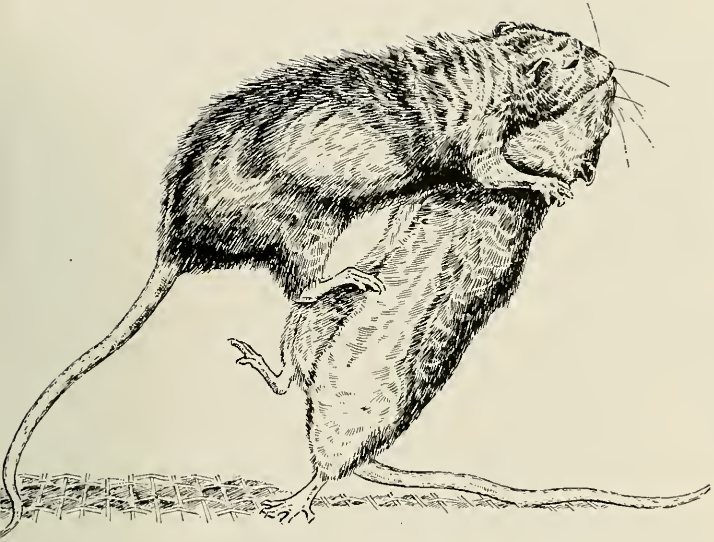
The attacks by residents on strangers are typical examples of territorial behavior. The conventional definition of a "territory" is a "defended area." In wild rats, territorial behavior is, with one exception, confined to males. The exception is the behavior of a female with young nestlings, and she defends not a large area, but only the nest itself—and even that not invariably. Granted that male rats indulge in territorial fighting, there is still the question whether they also fight for females. At first, during the study of experimental colonies, it seemed certain that they did; but, when detailed observations were made, it was found that there was no fighting for females at all. When a female was in heat, one or more males concentrated on copulating with her—an act which in rats can be repeated at intervals of a minute or two over long periods; there was no competition, and the female was quite indiscriminating.

THEN what, it may be asked, are we to make of the high mortality among the males in mixed colonies, when in all-male colonies there are few or no deaths? A likely explanation is that it is due to a kind of "overflow" fighting, resulting from excitation evoked by females not in heat. In this case, the males, stimulated but frustrated, turned to fighting among themselves—although ordinarily, in this particular colony, there was little conflict.

The fighting in the colony just mentioned was harmless: the males concerned thrived throughout the ten weeks of the experiment. This was because the way in which the colony had been set up was exceptional: it had begun as an all-male group — a peaceful one as usual, and females had been added later. Evidently, by the time their subversive influence appeared, the males resembled one big, happy family, and not any number of females could evoke really serious fighting among them. They were behaving, in fact, like the members of a family group — among whom fighting never, as far as present knowledge goes, occurs.

How is this inhibition against fighting a member of the colony maintained? It seems that a group odor is responsible for it, but we have little detailed evidence. By analogy with other species, we might also expect that in stable colonies there would be some form of dominance hierarchy, or "peck order," among the males. In its simplest form, there would be a dominant or number one rat, with prior access to females, food, nesting places, a second rat that would give way only to the first, and so on. In fact, nothing quite like this was found. In colonies of adults who had previously been strangers to each other, three types of male could be distinguished. The most successful, which have been called alphas, were always large compared

RESIDENT LEAPS at a newcomer. Fights sometimes follow "amicable" reaction when newcomer initially enters colony.



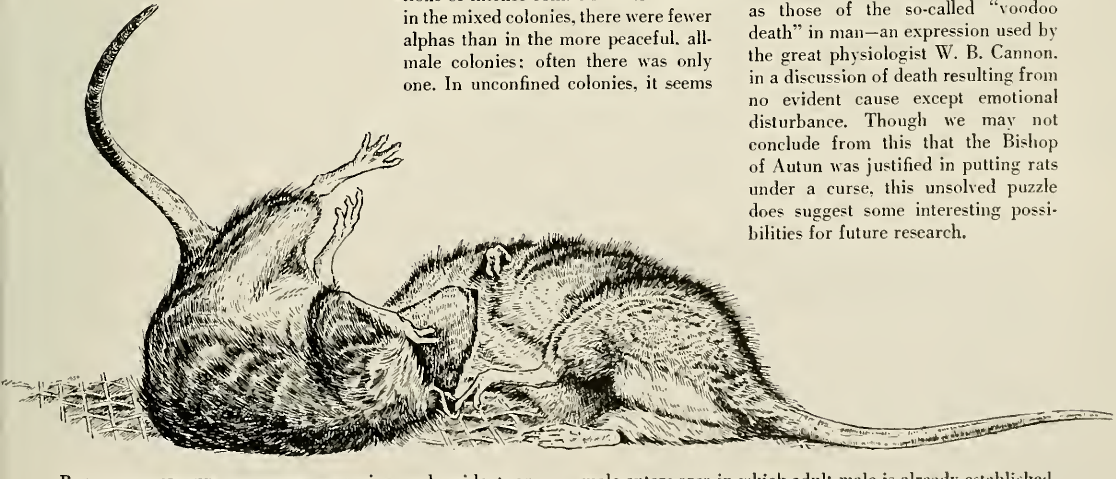
with other members of the colony; they moved about confidently, and if there were any fighting, it was the alphas that initiated it.

A SECOND type, the omegas, reached their status as the result of defeat by one or more alphas. In the experimental colonies, the omegas were marked by drooping posture and bedraggled appearance. They lost weight and died if not removed from the group. The third category comprises rats that, after defeat, adapted themselves to an inferior role: they have been called betas. They endured defeat without severe "shock" and fed with enough freedom to enable them to gain in weight. Betas and omegas associated together without conflict: there was no "hierarchy" among them.

There was no uniformity in the numbers of alphas, omegas, and betas in the small colonies studied, but one regularity was observed: in the conditions of intense conflict, which existed in the mixed colonies, there were fewer alphas than in the more peaceful, all-male colonies; often there was only one. In unconfined colonies, it seems likely that the adult males vary in status from alpha to beta; any rat with omega status would soon die or emigrate from the colony.

BUT in the last sentence, a question is implied: What do rats die of, in these conditions? This is one of those questions, obvious enough, that tend to go, not only unanswered, but also unasked. It is mentioned now because it would be wrong to give an account of the life of the wild rat—or of any other species—that implied that there were no more major problems to solve. It has been possible to show conclusively that rats under attack may die though quite unwounded; and that sometimes they die so quickly that there is no question of starvation through being barred from food (though that may be a factor on occasion). The rats die from "shock." To say this is, however, hardly more meaningful than to say that they die from fright or from humiliation. Some of the physiological changes that these rats undergo are the same as those produced by forms of "stress" such as acute infection, exposure to severe cold, and so on, and the expression "social stress" has been used to describe this condition, but it is still only a descriptive term.

Rats, in fact, sometimes die in circumstances seemingly as mysterious as those of the so-called "voodoo death" in man—an expression used by the great physiologist W. B. Cannon, in a discussion of death resulting from no evident cause except emotional disturbance. Though we may not conclude from this that the Bishop of Autun was justified in putting rats under a curse, this unsolved puzzle does suggest some interesting possibilities for future research.



ROLLING ON GROUND, newcomer *norvegicus* and resident, *on right,* continue battle. Fights occur most commonly when a male enters area in which adult male is already established. Newcomers died in eighteen of twenty such cases studied.

FIGHTING AMONG BIRDS

Use of dummies and a high-speed flash have led to new observations

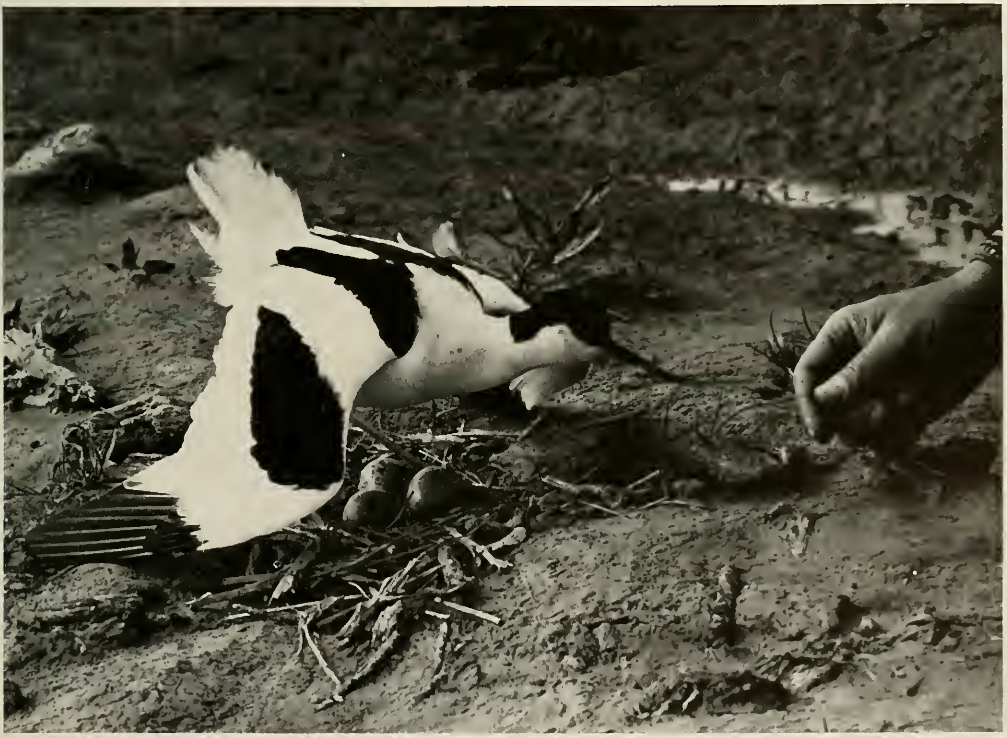
By Stuart Smith Photographs by Eric Hosking

We have always been interested in the displays of birds, both their nuptial displays and the aggressive displays by which they threaten other birds, to drive them away from their territories or food. At first, we had to content ourselves with watching these at a distance, through binoculars; but we were anxious to obtain really first-rate photographs, and this was hardly possible unless we could induce the birds to come near us and do their displaying at a certain spot on which our hidden cameras were already focused.

In this we finally succeeded, by making use of stuffed birds, which we placed in the territories of other birds, often near their nests. But the movements made by the displaying and attacking birds were frequently so rapid that ordinary photography was out of the question. We therefore developed, with the aid of Dr. P. S. H. Henry, a well-known, English electronics scientist, a flash apparatus that enabled us clearly to photograph the moving birds at speeds of about 1/5000 of a second.

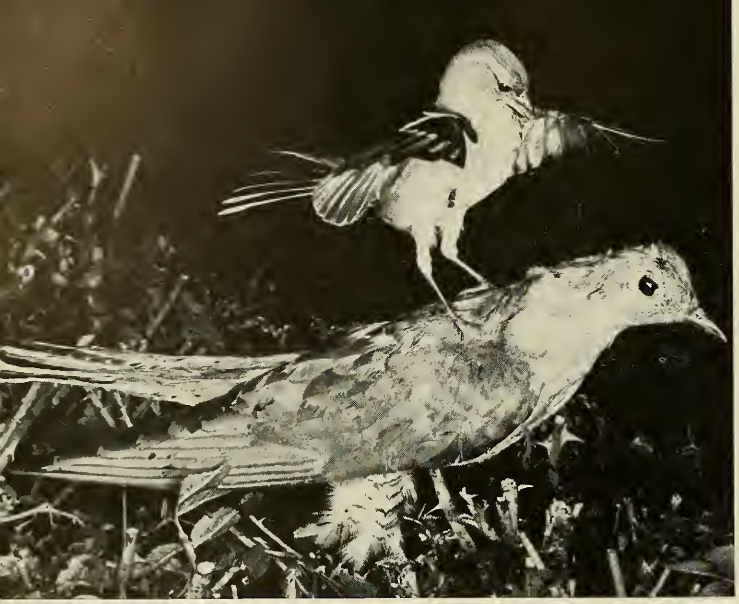
Dr. Smith, a research biochemist by profession, has collaborated with **Mr. Hosking**, the well-known British photographer, on a detailed study of avian aggression, *Birds Fighting*.

We first tried our new technique on ringed plovers, and the success we obtained with these prompted us to extend our experiments to other wading birds. So, the next spring, we journeyed up into the Cairngorm Mountains of Scotland where, along the rivers that flow from the hills, many oystercatchers breed. And finally we turned our attention to birds of the great passerine order, to which the songbirds and perching birds generally belong. Herewith, are some of the photographs we took, together with the stories they tell.



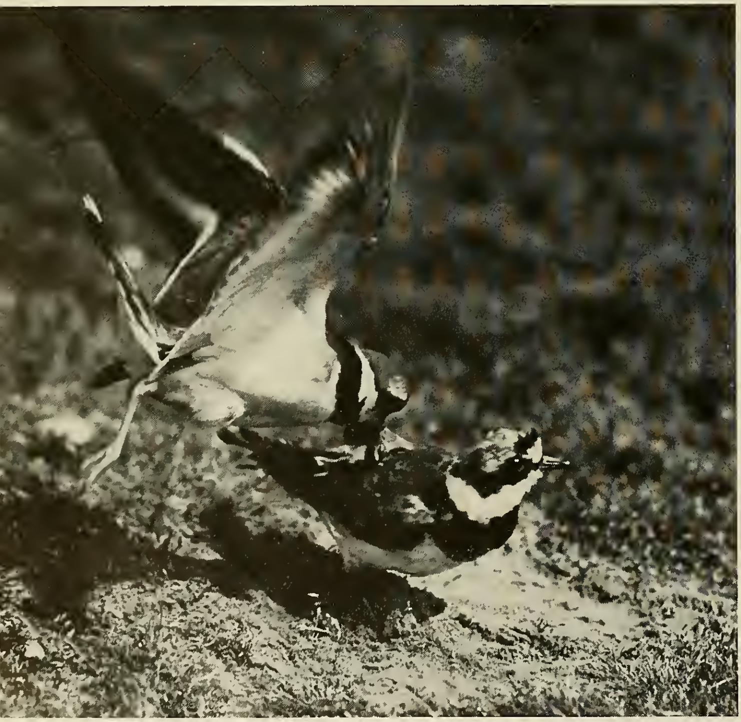
Male blackcap, *Sylvia atricapilla*, at left, attacks an effigy placed as intruder by its own nest. The bird attacked at once, first rising into the air, then diving as it uttered shrill cries.

Display of avocet, *Recurvirostra avosetta*, photographed on Dutch polder, was directed not at another bird but at the authors themselves when they approached eggs in her nest.



Female chaffinch, *Fringilla coelebs*, attacks dummy cuckoo, *above.* Hostility to the cuckoo, a parasitic bird which deposits its eggs in other birds' nests to be hatched, was observed to be very strong among many of passerine species.

Nightingales, *Luscinia megarhynchos*, also attack the decoy cuckoo, directing their blows at dummy's head and nape

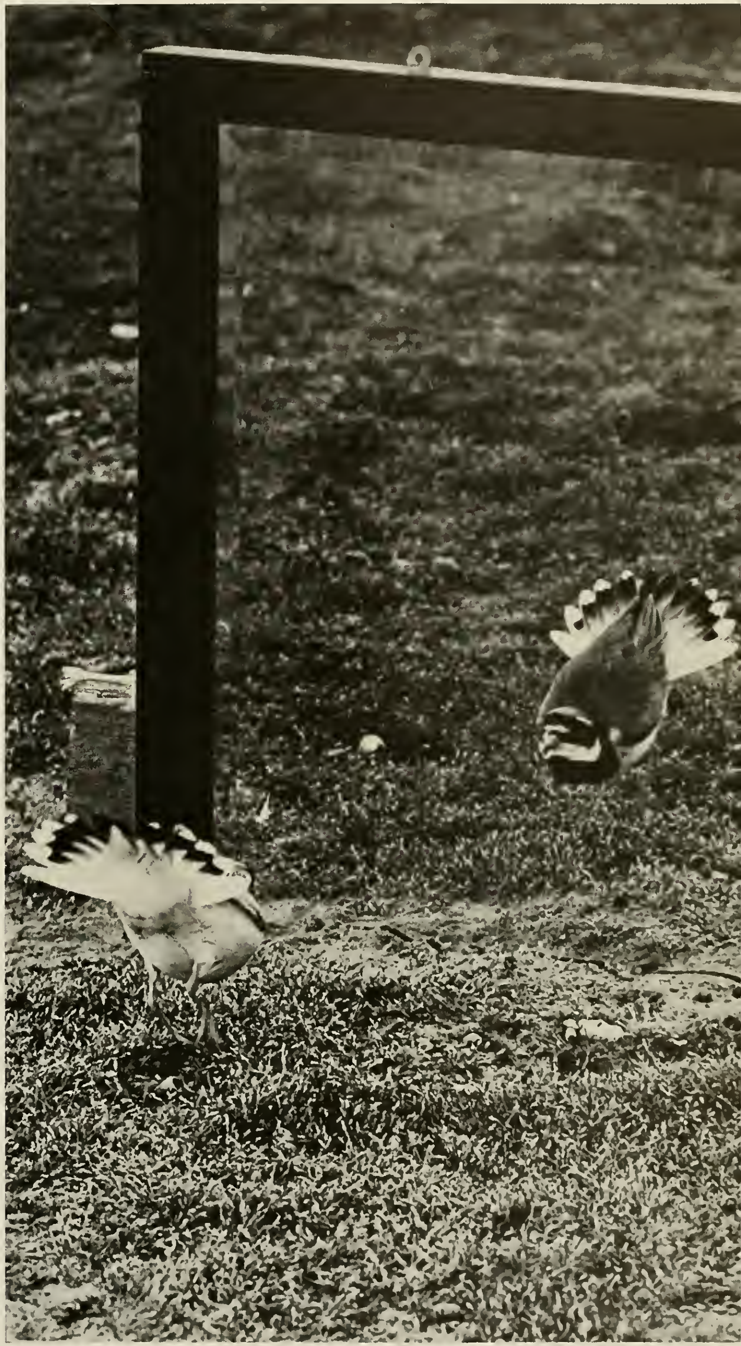


Mid-flight attack is made by ringed plover, *Charadrius hiaticula*, seen as it strikes dummy with foot. Plover first made a series of displays, puffing and erecting feathers with its head lowered, and attacked because decoy stood firm.

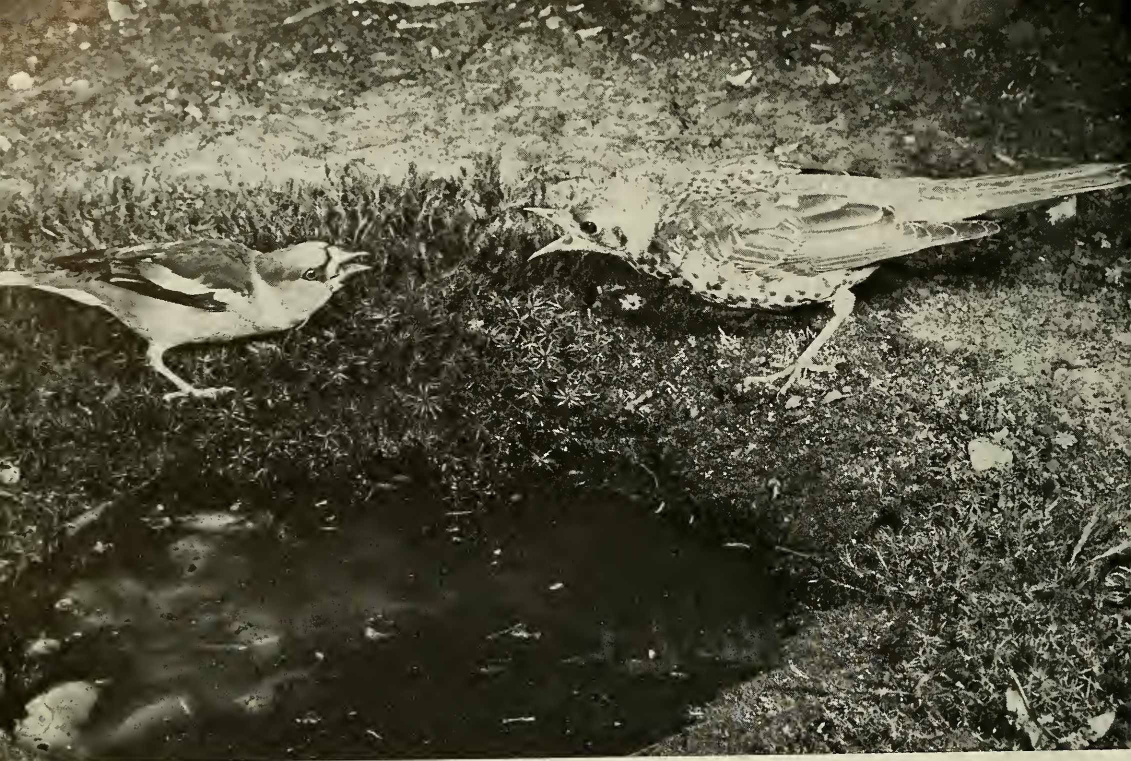
Excited oystercatcher, having failed to drive invader from nest by displays and cries, here strikes out at its head.

of its neck. Impulse to attack cuckoo is so powerful that some birds attack head alone if it is mounted on a stick.

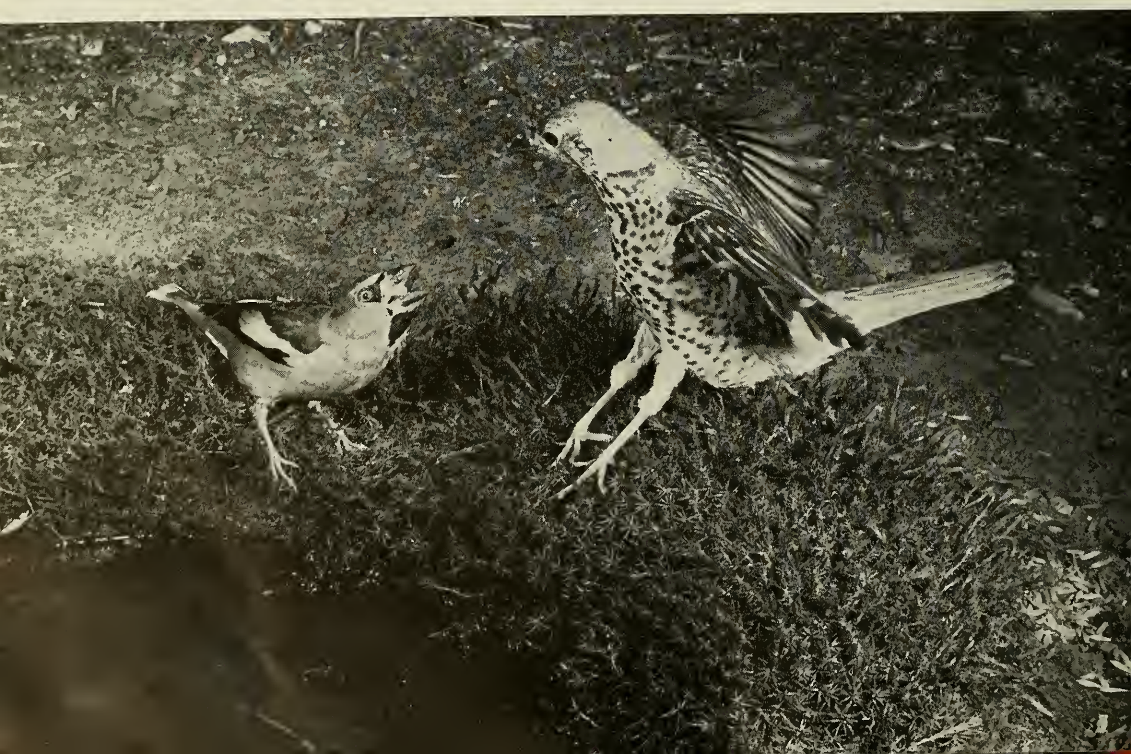
Oystercatchers, *Haematopus ostralegus*, are normally sociable birds, but they become aggressive in breeding season.



Displaying before mirror, the ringed plover above becomes its own adversary. Authors decided on mirror when attacks on stuffed dummy damaged it beyond use, and saw mirror's advantage: image "responds," inciting birds all the more.



Poolside combat breaks out when hawfinch, *Coccothraustes coccothraustes*, and mistle thrush, *Turdus viscivorus*, come to drink at same time. Birds confront each other defiantly, *above;* then hawfinch lunges, *below,* repulsing bigger bird.



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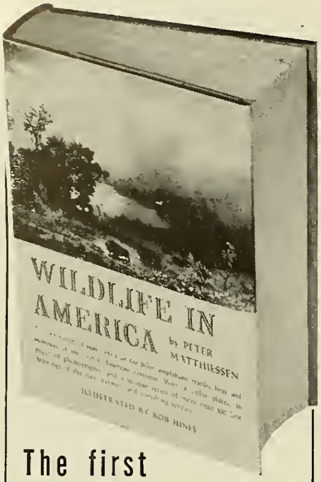

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WILDLIFE in AMERICA

by PETER MATTHIESSEN

Introduction by Richard H. Pough

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REVIEWS

(Continued from page 494)

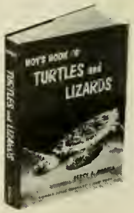
tremely unconvincing tale with a few later claims, some even less convincing and some hardly pertinent. The Marquis de Wavrin (on other evidence an honest but credulous traveler) passed on a hearsay report of a large *tailed* monkey, which he had not seen but had heard. (In the jungle you can hear anything you fancy, or what you hear can be anything you want.) Obviously, this unseen tailed monkey was not "*Ameranthropoides*," but Heuvelmans gratuitously suggests that someone confused a spider monkey with the ape, which therefore exists! Then one Roger Courteville claimed to have met and fought one of Loys's great apes. Although he gives Courteville's account at length, even Heuvelmans admits that it was a fake inspired by Loys's story. Several other supposed sightings at points hundreds or thousands of miles apart are adduced as further evidence by Heuvelmans, but all were given at second- or third-hand some twenty or thirty years after the claimed events.

The Sierra de Perijá, where Loys photographed his animal, is still a difficult region, but it has been explored by many collectors and scientists in the almost forty years since Loys was there. Except for the obvious faker Courteville, no one has reported seeing an unusually large or tailless monkey there or hearing any rumor of one.

In short, the only objective evidence is a photograph indistinguishable from that of a well-known spider monkey. All the other evidence is either manifestly unreliable hearsay or open to strong suspicion, at least. Yet Heuvelmans' conclusion is that the existence of a South American great ape cannot be disputed "except by the disingenuous or the blind." I need not belabor the point.

I DO NOT mean to say that all of Heuvelmans' conclusions are on such an absurd level or that he is completely credulous. He does dismiss a fake still more obvious than Courteville's and even remarks that the perpetrator, a former racing driver, "has no scientific standing." He also remarks that a migration route for the animal, a supposed dinosaur in New Guinea, never existed; but in the next chapter, he thinks it quite likely that dinosaurs do survive in Australia, which would require just such a migration route. At one point, he even implies that an expedition's reporting *not* finding a rumored animal suggests that it does exist. He suspects that the party wanted to discourage others until they could capture the fabulous beast.

On the other hand, one must agree that the reports on the "abominable snowman," to which Heuvelmans naturally devotes much space, seem to have



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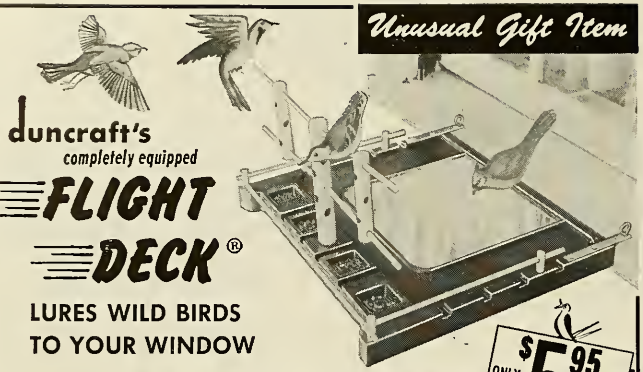

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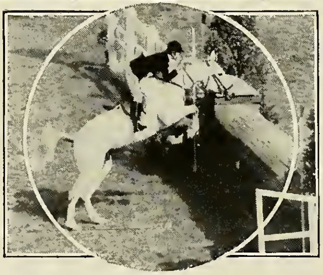

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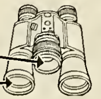

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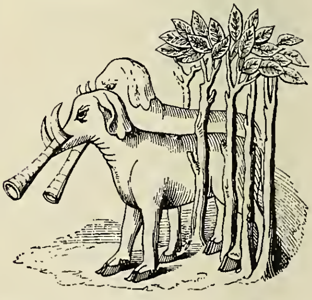
a hard core of fact within the mass of contradictory and sometimes ridiculous accounts. Heuvelmans' conclusion that it is a surviving *Gigantopithecus* (an ape known from fossils in the Pleistocene of China) is premature, to say the least, but there probably is some animal that makes "yeti" tracks. It may be something new or something already known. Such specimens of the fabulous nandi bear of eastern Africa as have reached zoologists turned out to be ratels, rather uncommon animals that have nevertheless been known to zoologists since the eighteenth century. Heuvelmans still maintains that the nandi bears that were not collected were something else, and this brings up another pertinent point. When zoologists have investigated the regions where strange animals have been persistently reported, they have either found the animals forthwith or have, until now, never found them. There is some probability that they do quickly find the real ones. Perhaps the "abominable snowman" will be the exception.

By sheer force of numbers, Heuvelmans and the other romantics may well have predicted some discovery that will actually be made; if you buy most of the tickets in a lottery, you are likely to win on one. Their judgment of probabilities is certainly too sanguine, their interpretations of evidence vastly too charitable, and their whole attitude more enthusiastic than judicious. Nevertheless, they are highly entertaining, and no harm is done if they are not taken too seriously. The romance is delightful even when the science is shaky.

IN BRIEF



Elephants in British Museum manuscript.

Elephants, by Richard Carrington. *Basic Books, $5.00; 272 pp., illus.*

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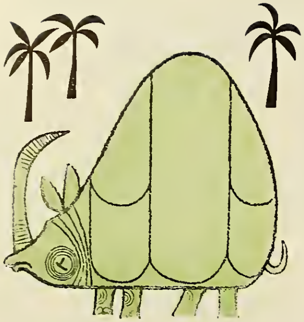

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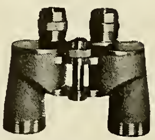

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and their relatives once numbered over three hundred species, whose main characteristics are discussed here with thoroughness and clarity. Carrington concludes with a rather sketchy survey of the dealings of "Elephants and Man."

NATURE STORIES FROM THE VIENNA WOODS, by Lilli Koenig. *Crowell, $3.50; 159 pp., illus.*

ON opening this book, the reader thinks immediately of Konrad Lorenz. It is in his vein—intimate, lively, and documented with authority; but it has a special quality of its own. Mrs. Koenig writes, in an open and friendly style, about the animals she has known and studied during the course of work at a biological station in the Vienna woods. She shows a delicacy of feeling in discussing these animals, is never sentimental and always gay, is realistic but full of charm. The author's drawings and photographs, incidentally, are of a piece with her writing. A great deal of scientific knowledge has gone into the book, but its beauty comes from human sympathy and a willingness to love the unfamiliarity in other lives.

ANIMAL CAMOUFLAGE, by Adolf Portmann. *University of Michigan Press, $4.50; 111 pp., illus.*

THIS addition to the Ann Arbor Science Library maintains the high standard—and, alas, the relatively high price—set by its predecessors. The book consists largely of examples illustrating the phenomenon in question, and the author has tried to give its modalities some sort of classification. This does not always make the book as clear as it might be: we sometimes have trouble distinguishing one type of camouflage from another, and perhaps the effort is not worth making in every case. But Portmann's book has two great merits: since "camouflage implies a seeing eye from which to hide," Portmann stresses the role of vision; and the place of protective coloring in natural selection is also stressed, as is only fitting in a year devoted to the memory of Darwin.

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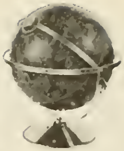

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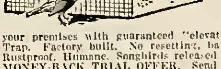

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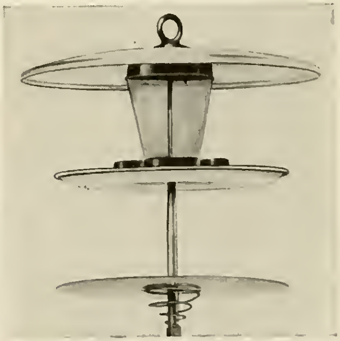

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ing undercurrent of concern about the effect the loving but dominant father had on his son Julian. the author's father. The latter suffered from trying to be more than John Burroughs' son.

THE STORY OF THE PLANT KINGDOM. by Merle C. Coulter. revised by Howard J. Dittmer. *University of Chicago Press, $5.00; 326 pp., illus.*

As Coulter's classic book first appeared in 1935. this revision of it is welcome indeed. It begins with a few chapters on the basic processes of plant life and the role played in them by the main plant parts. These are followed by discussions. comprising the bulk of the book, of the several plant groups, from algae to angiosperms. This is a textbook, but it is an uncommonly readable one; it constitutes the best survey available of plant biology, and should be read not only by college students. but by everyone interested in plant life.

THE TREE IDENTIFICATION BOOK. by George W. D. Symonds. *Barrows, $10.00; 272 pp., illus.*

An extremely complete and helpful guide. Its large format rules it out as a field trip adjunct. but its unusual method of presentation recommends it to both amateur and professional naturalists. The book is divided into two sections. The first consists of genus identification, and separately groups leaves, twigs, flowers, fruit, and bark of some 130 trees. Each of these refers by a simple page reference to the second section, in which species are identified. Here. all details of any given tree are brought together. It is particularly satisfying to find that wherever possible photographs of tree details are reproduced in actual size. The book contains more than 1,500 illustrations, a tab index and a general index.

NOTE

John Hay's *The Run*, a book about the migration and spawning of the alewife, has recently been published by Doubleday. A portion of the work originally appeared in this magazine, to which Mr. Hay contributes regularly.

ERRATA

The Editors trust that readers of *Darwin and the Fossil Record* (October, 1959) were not confused by the typographical error that dated the *Beagle*'s voyage in the 1900's, rather than the 1800's.

This list details the photographer, artist, or other source of illustrations. by page.

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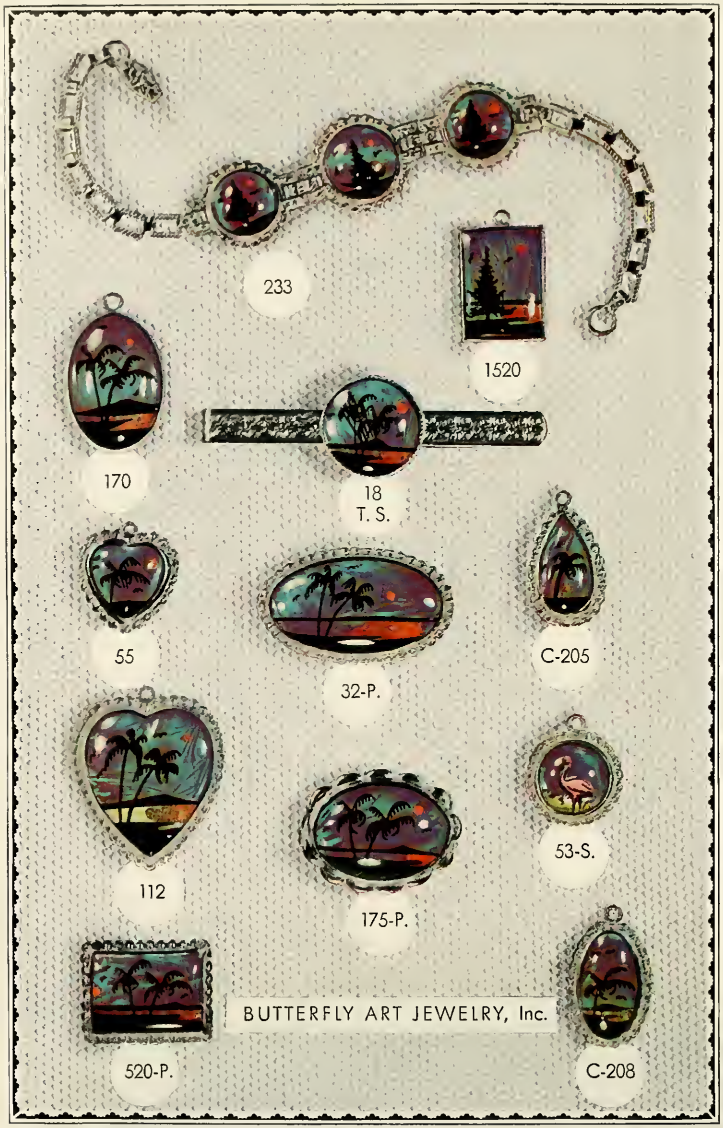

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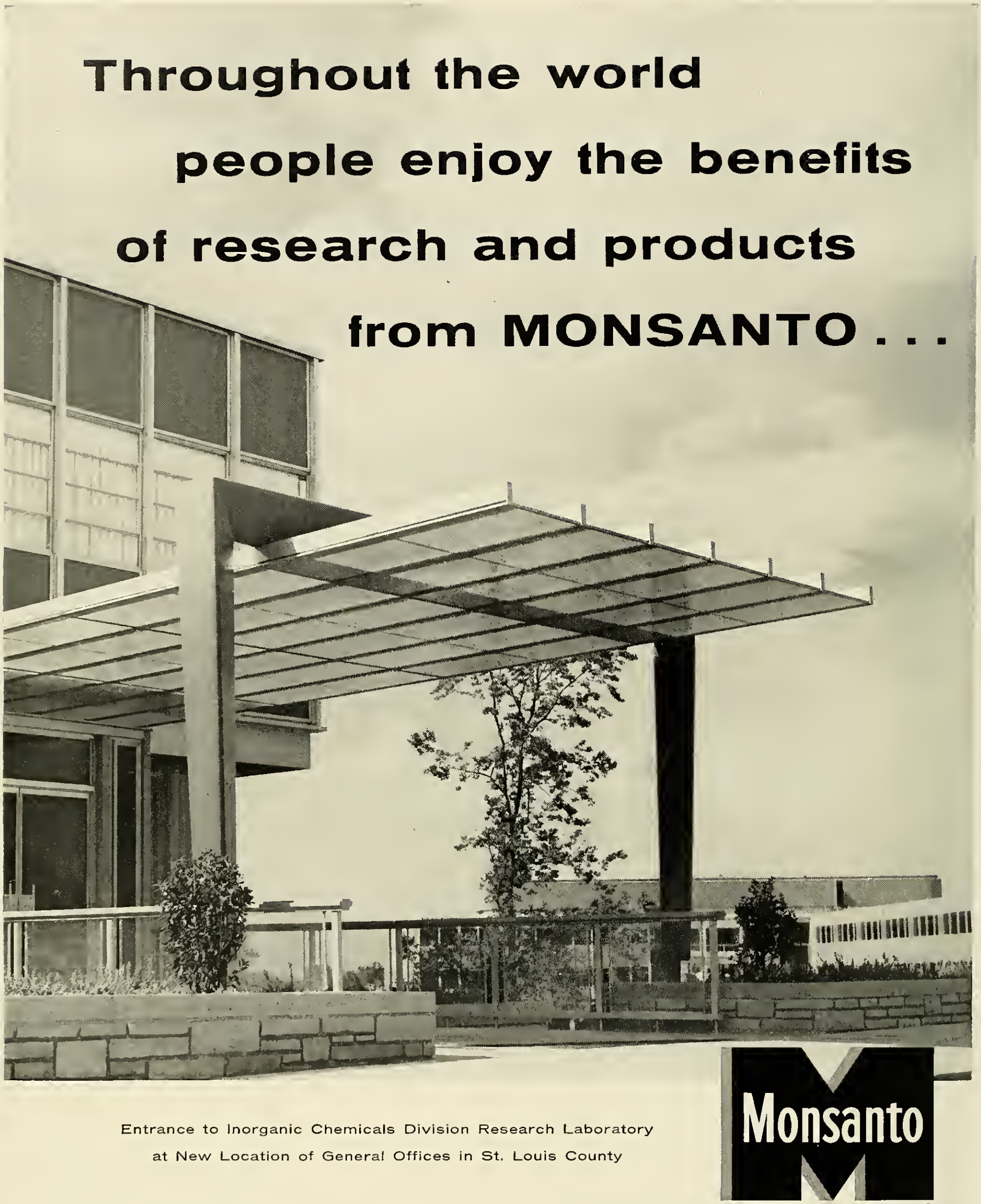
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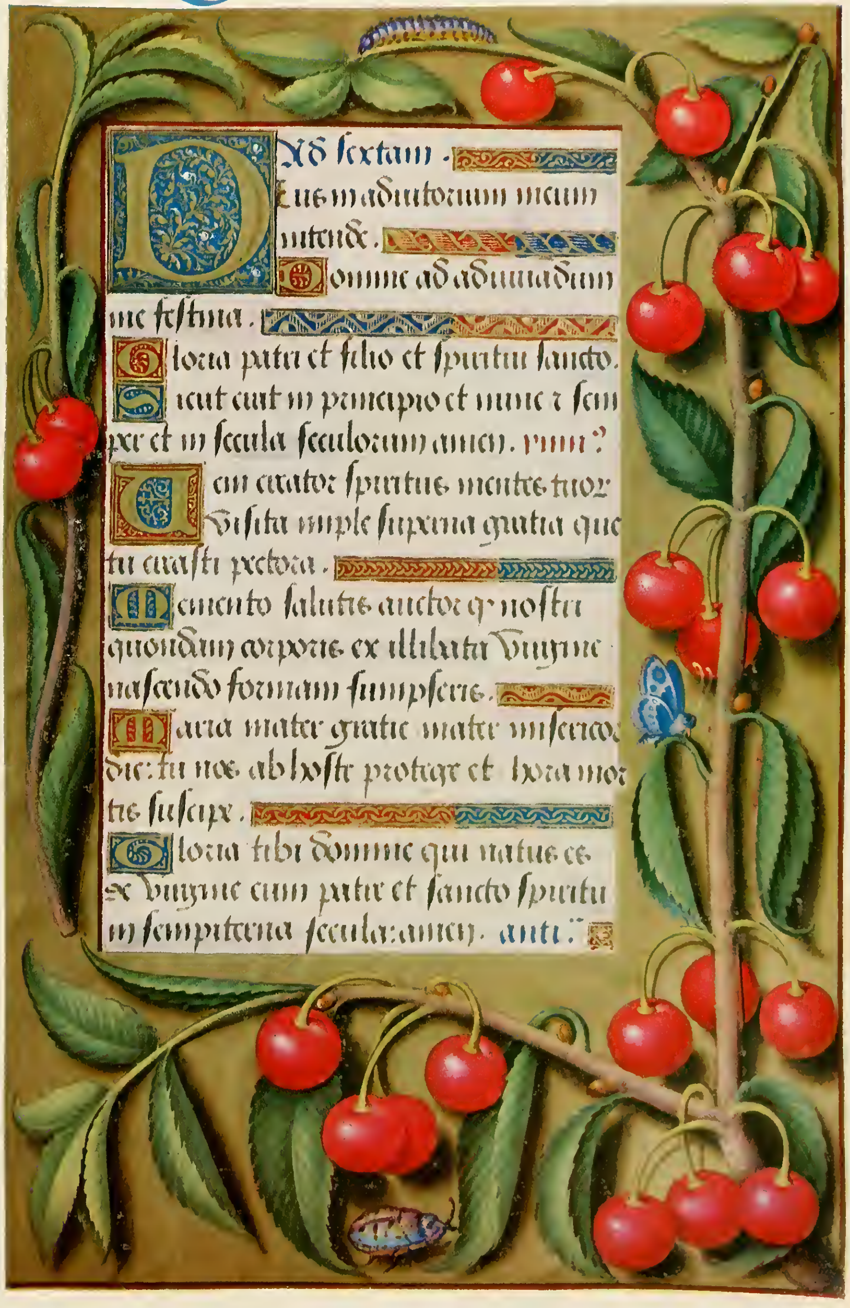

Ad ſextam .

Deus in adiutorium meum
intende .
Domine ad adiuuandum
me feſtina .
Gloria patri et filio et ſpiritui ſancto.
Sicut erat in principio et nunc ⁊ ſem
per et in ſecula ſeculorum amen. ymn⁹
Veni creator ſpiritus mentes tuor
viſita imple ſuperna gratia que
tu creaſti pectora .
Memento ſalutis auctor q' noſtri
quondam corporis ex illibata virgine
naſcendo formam ſumpſeris .
Maria mater gratie mater miſericor
die: tu nos ab hoſte protege et hora mor
tis ſuſcipe .
Gloria tibi domine qui natus es
ex virgine cum patre et ſancto ſpiritu
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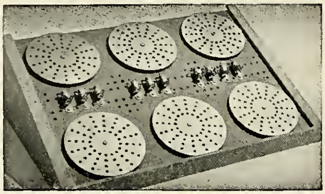

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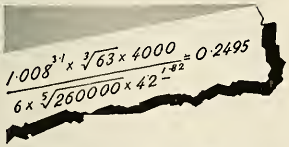
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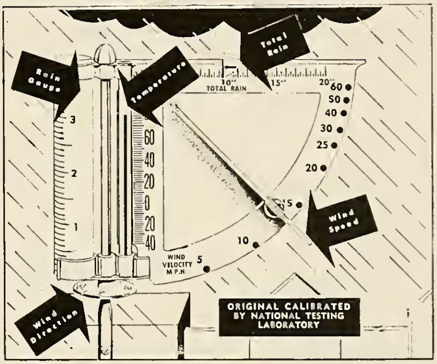

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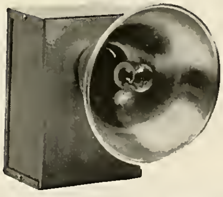

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December 1959

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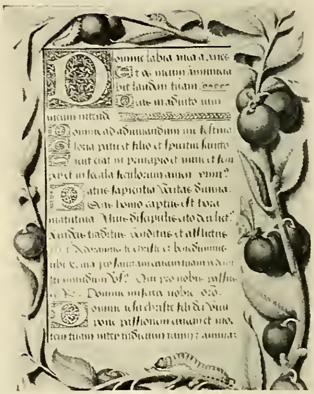

AT the end of the fifteenth and the beginning of the sixteenth centuries, Jean Bourdichon, a miniaturist, executed, on vellum, prayer books designed for special devotions of the French royal family. A cherry-bordered page from such a manuscript is this month's cover.

Those early days of the Renaissance saw a great revival of medical botany — an interest mirrored in the paintings of Bourdichon, and, with the advent of printing, in the compendia of medical and household lore known as herbals.

One such herbal says the cherry "maketh one well coloured," but warns that the fruit should not be sold in plague time in "well governed common wealthes."

For more of Bourdichon's paintings and a review of medical botany as found in Renaissance herbals, turn to page 578.

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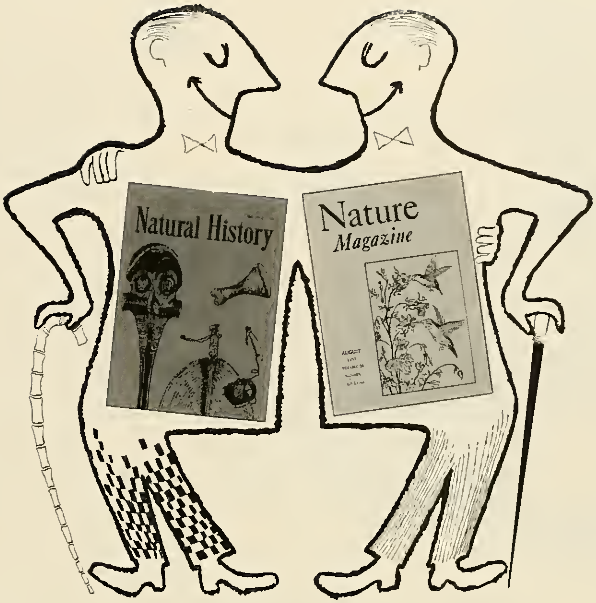
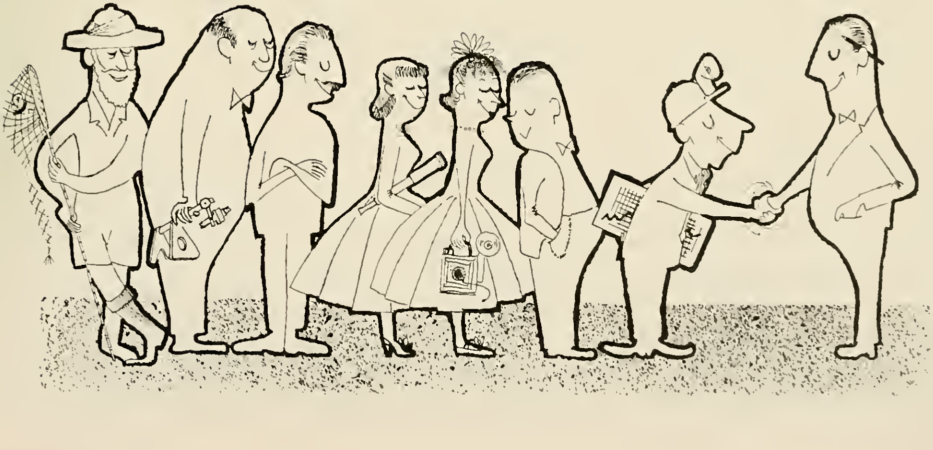
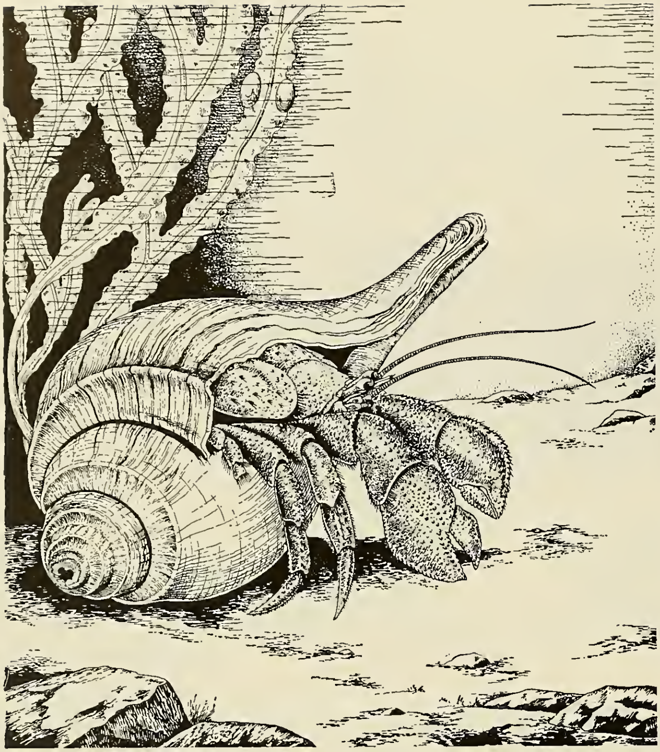


ANNOUNCEMENT

The trustees of The American Museum take great pleasure in joining with the officers of the American Nature Association to announce the impending merger of Natural History and Nature Magazine. Starting with the issue of January, 1960, both distinguished publications will appear within a single cover and under a single title. Readers of Natural History will enjoy the addition of many outstanding features that have previously appeared exclusively in Nature Magazine. The editors of Natural History, in turn, welcome both the members of the American Nature Association and other readers of Nature Magazine to these pages.





HERMIT CRAB inhabiting a whelk is from *Wild Folk at the Seashore*, by C. L. Fenton.

Reviews

CHILDREN'S BOOKS FOR CHRISTMAS

CHRISTMAS is upon us, and with it the problem of choosing gifts for our young friends and of recommending gifts for our readers' young friends. On our part, we are, embarrassed, as usual, feeling our years perhaps a touch more than we did last Christmas. Accordingly, we have, also as usual, turned to our sister publication, JUNIOR NATURAL HISTORY, for help. Herewith, her suggestions:

GENERAL

This is Nature, selected and edited by Richard W. Westwood (Crowell), is a book of articles and stories by well-known naturalists, which have appeared in *Nature Magazine.* They represent a happy fusion of trained commentary and simple description of events, and seem certain to encourage interest, or create it where it is lacking. Drawings and photographs add to the completeness of the book. $5.95, 214 pp.; all ages.

Soon After September, by Glenn O. Blough (Whittlesey), is another of Dr. Blough's books in the science-nature series. The author introduces the child to what he calls "The Road of Seasons," and the wildlife of all kinds one meets en route; but the season he particularly emphasizes is late fall. The book, written in a direct and lively style, is well illustrated with black-and-white and color drawings. $2.50, 48 pp.; ages 7-11.

ASTRONOMY AND SPACE

Experiments in Sky Watching, by Franklyn M. Branley (Crowell). Here is a workable, "do-it-yourself" astronomy book that will satisfy those who are curious about the sky but lack a telescope. Rulers, smoked glass, cardboard, windows lined with trees, hills, or buildings are just a few of the simple "tools" the author puts to use in many easy-to-follow experiments. A ten-year calendar showing the positions of the planets is included, and lunar eclipses to be seen in the United States are dated for twelve years ahead. The book is informative, easy to follow, accurate, and well illustrated. A list of books for further reading is given. $3.50, 111 pp.; ages 10 and up.

The Story of Flight, by John Lewellen and Irwin Shapiro (Golden), is a beautiful book. Clear and condensed, it covers a very wide span of time—from before written history to the spaceman of tomorrow. It is a large book, illustrated with old prints, photographs, and original paintings and drawings. $3.95, 96 pp.; ages 9-12.

The Rocket Handbook for Amateurs, edited by Lt. Col. Charles M. Parkin, Jr. (John Day), is topical, to say the least. Young people seriously interested in rockets will find basic information about their safe construction, testing, and launching, and a plan for doing same is included. The author wisely suggests that youngsters work with an organized rocket club to benefit from the expert help now available through government sources. Well illustrated with many charts. $5.95, 306 pp.; ages 15 and up.

ZOOLOGY

Going from events in the sky to those of the sea, we find the *Aquariam Book for Boys and Girls*, by Alfred Morgan (Scribner's). The book is beautifully written, and in such a way that discussions of the physical characteristics and life habits of various creatures lead naturally to instructions on their care. The book will be especially useful to schools which include aquaria in their equipment. Drawings and photographs lend further interest. $3.00, 209 pp.; 9-14.

The Unknown Ocean, by Amabel Williams-Ellis, is another science explorer book (Putnam). The author suggests something of the mystery and excitement of the sea, and tells of a few of its scientific explorers in brief but interesting chapters. Scattered throughout the book are descriptive drawings. $2.00, 72 pp.; ages 8-12.

Finally, there is *Wild Folk at the Seashore*, written and illustrated by Carroll Lane Fenton (John Day). The tidal zone, being a kind of crossroads, is one of the most fascinating parts of our world, and the author presents it in narrative style, weaving together description and explanation. $3.50, 128 pp.; ages 9-12.

On the subject of mammals, we found several books to recommend; they follow a story-text approach wherein physical characteristics, habits, and habitats are informatively related, if not in depth:

Here Come the Raccoons! by Alice E. Goudey (Scribner's), is a simple account of the life story of four of these little creatures. A few of their more interesting relatives also appear. Illustrated with line drawings. $2.50, 94 pp.; ages 7-9.

Sinbad the Gorilla, by Alice M. Johnson (Vantage), offers text and photographs about a baby gorilla who came to Chicago's Lincoln Park Zoo, and it might almost save one a trip to see the real thing. $1.95, unnumbered pp.; ages 4-8.

Whitefoot Mouse, by Barbara and Russell Peterson (Holiday), concerns a familiar animal, but it also relates the life of an entire animal community and emphasizes the importance of food chains in wildlife as a whole. Well illustrated. $2.50, 53 pp.; ages 7-10.

Pigs, Tame and Wild, by Oliver L. Earle (Morrow), are briefly but entertainingly presented here. There are facts about their history, anatomy, habits, varieties, relatives, etc. Well illustrated by the author. $2.50, 64 pp.; ages 7-10.

The Weasel Family, by Charles L. Ripper (Morrow). Children often have aversions to (based on preconceived ideas about) some of our wildlife, and this accurate book will serve a valuable purpose. $2.50, 64 pp.; ages 7-11.

The Porcupine Known as J.R., photographs by Will Vandivert, story by Rita Vandivert (Dodd, Mead), is a delightful picture book. J.R. comes into the family circle as a prickly handful, has many comic adventures and stays to become an "indoor" porcupine. $2.75, unnumbered pp.; all ages.

Still on the subject of mammals, we found several books more fully developed in theme. *Animal Habits*, by George F. Mason (Morrow), is the latest book in a series by this writer-artist. Many aspects of animal behavior are discussed, but they are given merely as the remarks of an observing naturalist, with nothing doctrinaire or theoretical about their presentation. The book may stimulate a more thoughtful and accurate interpretation of animal behavior, uninfluenced by the anthropomorphism of so many writers. Well illustrated. $2.50, 93 pp.; ages 9-15.

Animals That Help Us, by Carroll Lane Fenton and Herminie B. Kitchen (John Day), develops in a most understandable and compact style the story of man's domestication of mammals for use and for pets, from the late Stone Age to the present day. Not a weighty text, but quite informative, even so. Illustrated with drawings. $3.50, 128 pp.; ages 9 and up.

For children interested in pets there is *Wild Animal Pets*, by Roy Pinney (Golden). Well planned and colorful, it contains much useful information about the choice, feeding, and general care of part-time and full-time pets. The author also stresses the value of domesticated animals in developing an interest in and sense of responsibility for life in the wild. With delightful color photographs. $1.95, 67 pp.; ages 7-15.

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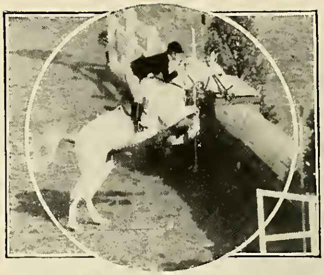

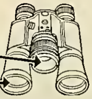
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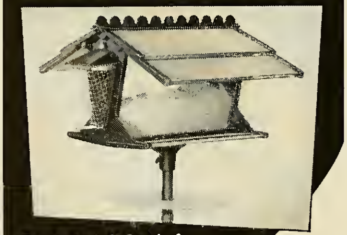
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Brooksbank (Dutton), consists of a number of amusing stories of the author's almost human chimpanzee friends, Jonny, Congo, and Nyanya. The author manages to convey his respect and affection for those creatures, whom he got to know in their natural habitat. Photographs. $2.95, 191 pp.; ages 12 and up.

Boy's Book of Turtles and Lizards, by Percy A. Morris (Ronald), is quite easy reading about an interesting subject for young naturalists. The text identifies, explains, and advises about turtles and lizards indigenous to the United States. A section is devoted to reptiles suitable as pets, whose care and housing in home terrariums are carefully explained. Illustrated with many photographs. $4.50, 229 pp.; ages 10 and up.

Insect Builders and Craftsmen, by Ross E. Hutchins (McNally), treats of some of the most interesting insects. A conversational style is used throughout, and the quality of the photographs, taken by the author, is excellent. We liked the book's dedication, which seemed to indicate the author's sympathy with his intriguing subject: "To the busy insects whose labors were so often interrupted by the camera's eye." $2.95, 96 pp.; ages 10-15.

BOTANY

Trees, William M. Harlow (Dover), is a pocket-size book with an uncluttered text, written in a semipopular style that is useful to the beginner as well as to the more serious student. A concise introduction gives the reader enough information for general identification, and an eight-page synoptic key makes it possible to locate the genus of any tree one is likely to see. Supplementary keys in the main text permit easy location of the various species. Illustrated with photographs. $1.35, 288 pp.; ages 12 and up.

Plants That Heal, by Millicent E. Selsam (Morrow), is an intimate little book about plants possessing healing properties. The author begins with the herbs of a bygone age and moves up to modern, plant-derived drugs. The common and scientific names of curative plants are listed in the back of the book. Drawings. $2.50, 96 pp.; ages 9-12.

Grasslands, by Delia Goetz (Morrow), is about that most important of plants. The book is a combination of narrative, description, and explanation, simple in style but substantial. Different areas of grassland over the world, the animals living there, and the changes wrought by man are all discussed. Well illustrated. $2.75, 64 pp.; ages 8-12.

MINERALOGY AND GEOLOGY

Turning to the treasures beneath the ground, we found *1001 Questions Answered About the Mineral Kingdom*, by Richard M. Pearl (Dodd, Mead).

(Continued on page 616)

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BY HENRI LHOTE

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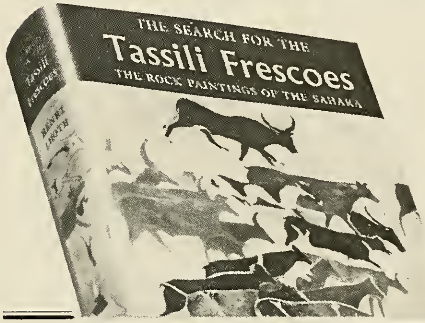

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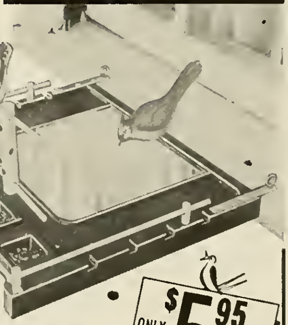

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RHINOCEROS FALLS into a trap in the Kaziranga Wildlife Sanctuary in Assam, India. Here, rigid protection of the great beasts has allowed them to thrive, unlike rhinos in other areas. As a result, the Indian Government is able to permit, under strict supervision, the legal trapping of a few of the animals for exhibition at approved foreign zoos.

MARCO POLO'S UNICORN

The Indian rhinoceros fights for its existence as humans hunt it and encroach on its habitat

By Lee M. Talbot

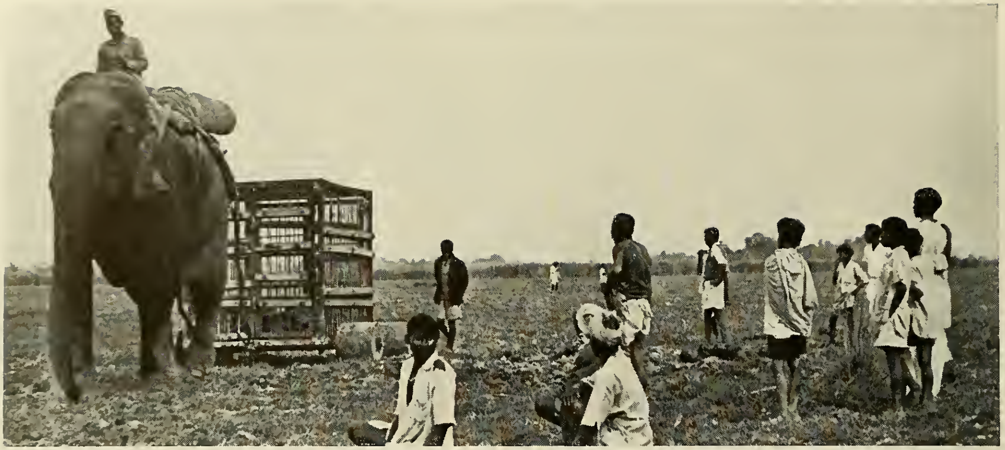
THE WORLD HAS LOST at least one hundred and seven kinds of mammals since the time of Christ, and most, if not all, of these departed species and subspecies owe their extinction to man's activities. These same activities, today, have brought at least another six hundred forms to the point where they may be considered threatened with a similar fate.

Perhaps at first thought a hundred extinctions spread over two thousand years does not seem a particularly urgent matter. The urgency becomes clear, however, when one considers that the rate of extermination—like the rate of the world's human population growth, with which it is closely associated—has sharply accelerated in recent years. Nearly seventy per cent of the losses have occurred in the last century and almost forty per cent within the last fifty years. Put another way, up to A.D. 1800, one kind of mammal was exterminated each fifty-five years; during the next century, the rate increased to one each year and a half; and, since 1900, man has exterminated roughly one form every year! And this number refers only to mammals. No one has made a similar tally of reptiles, amphibians, fishes, or insects; but we do know that since 1689, when the last dodo is thought to have died, over a hundred other bird forms have been exterminated in one way or another.

Man accomplishes this destruction in two ways. The obvious way to destroy an animal is to kill it. Throughout history, mankind has hunted or trapped animals for the sake of animal products, for protection, to remove competition, and for sport. Less obvious than killing, but far more threatening to the species' survival, is habitat modification—indirect and often unintentional destruction. An animal does not exist by itself, isolated and independent. Rather, it might be considered as the center of a complex ecological web, whose radiating strands are the animal's requirements for or associations with food, water, cover, climate, disease, parasites, and predators. All these strands, in turn, are interconnected and make up, in sum, the animal's whole habitat. The animal's survival may depend on the web being intact.

A few human activities—such as cultivation, flooding, and tract construction—virtually annihilate entire habitat webs and the results are easy to see. Less easy to recognize are the effects of those human activities that alter only a part of existing habitats. Livestock-grazing, too, acts on the habitat web through direct competition for food and water, alteration of vegetation, erosion from overgrazing, and the introduction of parasites and diseases. Fire alters or destroys vegetation, soils, and watersheds. Accidentally (or even intentionally) introduced exotic species compete with or prey on native species. Regardless of the form such habitat modification may take, it is an almost inevitable

Kaziranga Sanctuary provides visitors with facilities for viewing rhinoceros, *left*, from the back of elephant, *above*.



Heavy steel cage, which will hold the captured rhino, is moved on rollers into the area where a pit trap has already been prepared. Domesticated elephants, traditionally fearful of the rhinoceros, must be especially trained for this work.

concomitant of human activities; so much so that it is difficult to find any area of the earth's surface that has not been changed in some fashion by man. The extent and degree of this change are usually in direct proportion to the numbers of humans involved. Consequently, as the world's human population rapidly expands, animals with extensive or inflexible habitat needs are being literally squeezed out.

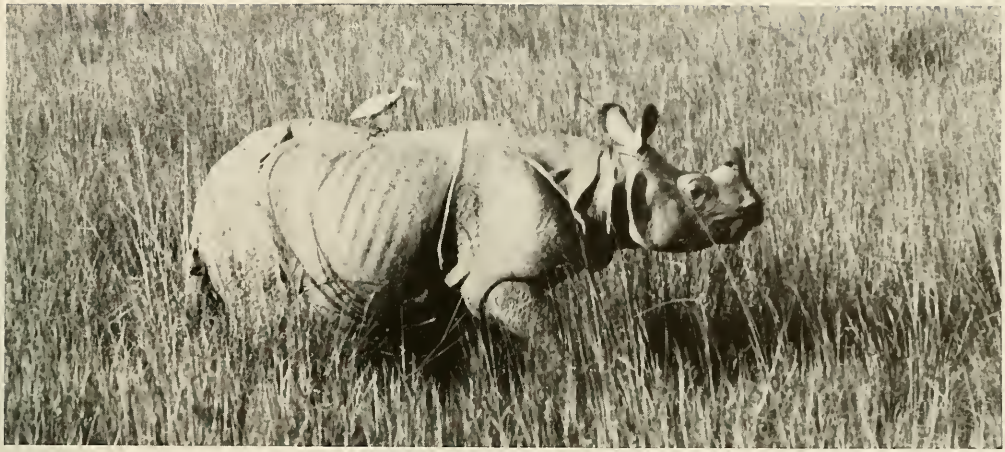
The great Indian rhinoceros, *Rhinoceros unicornis*, provides an outstanding example. In ancient times, the rhinos were among the most common and widespread land mammals. Today only five popularly recognized forms survive, the black and the white rhino, both of Africa, and the Javan, the Sumatran, and the great Indian rhino, of southern Asia. All of these are now considered to be threatened species.

The rhinos of Africa are widely known, but it comes as a surprise to many to learn that rhinos are also found in Asia. Interestingly enough, Western man learned of the Asian forms before he heard of the African ones. In 1298, Marco Polo wrote: "There are wild elephants in the country and numerous unicorns which are very nearly as big. They have hair like that of a buffalo, feet like those of an elephant, and a horn in the middle of the forehead which is black and very thick.... The head resembles that of a wild boar and they carry it ever bent toward the ground. These unicorns like very much to stay in the mud. It is a very ugly beast to look at and is not at all like the one our stories say is caught in the lap of a virgin. In fact, it is altogether different...."

The country of which Polo wrote was Sumatra, and his "unicorn" seems to be a composite of the Sumatran and Javan rhinos, both of which were found there at the time of his visit. Excepting one item, "hair like that of a buffalo," which is characteristic of the Sumatran rhinoceros, the Venetian traveler's description also well fits the Indian rhino.

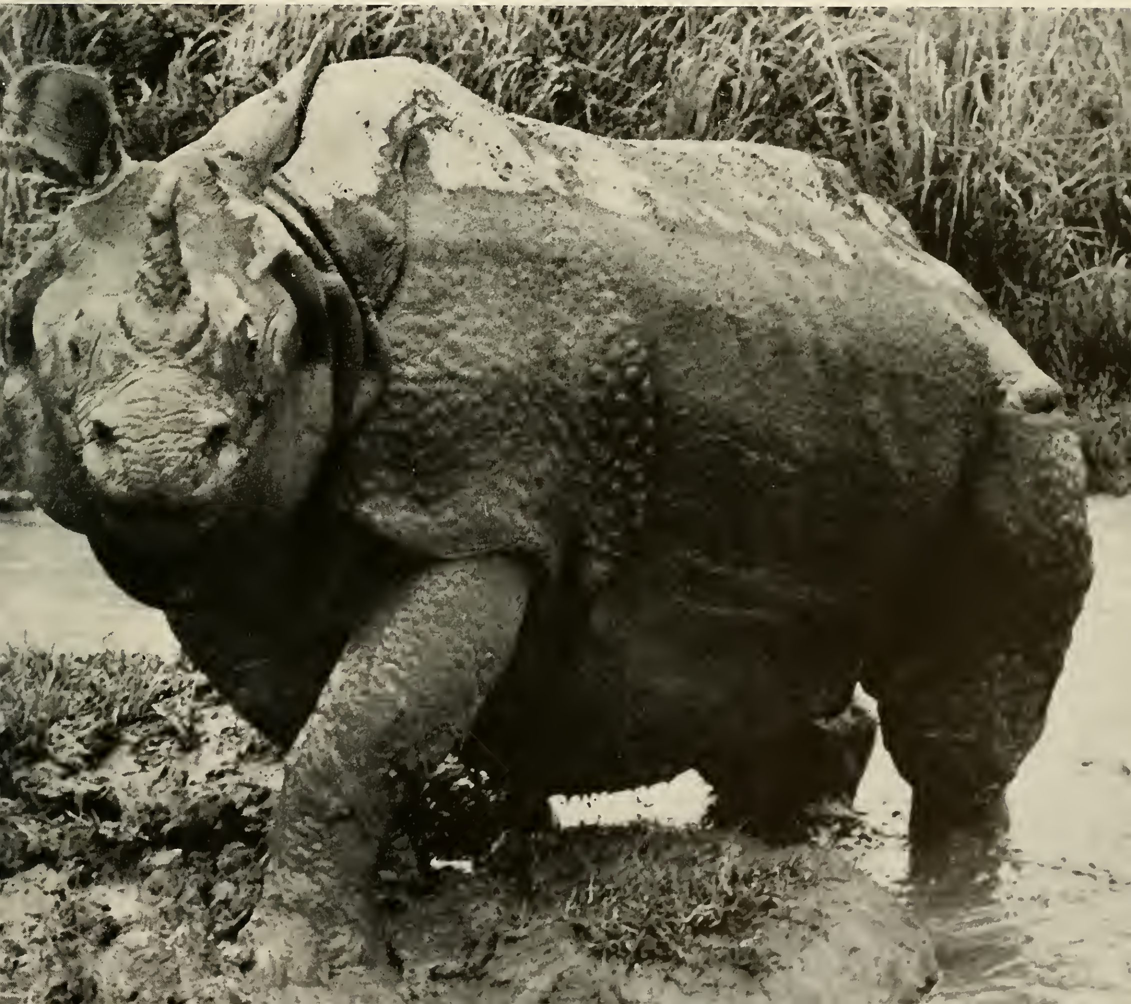
It is the largest Asiatic rhinoceros, and some individuals may reach a height of nearly six feet at the shoulder and a total length of more than fourteen feet. The weight of a large adult has been estimated at more than two tons. Its thick hide hangs in great folds, giving the appearance of armor plating. Rivet-like tubercles, studding the legs and flanks, further enhance this effect.

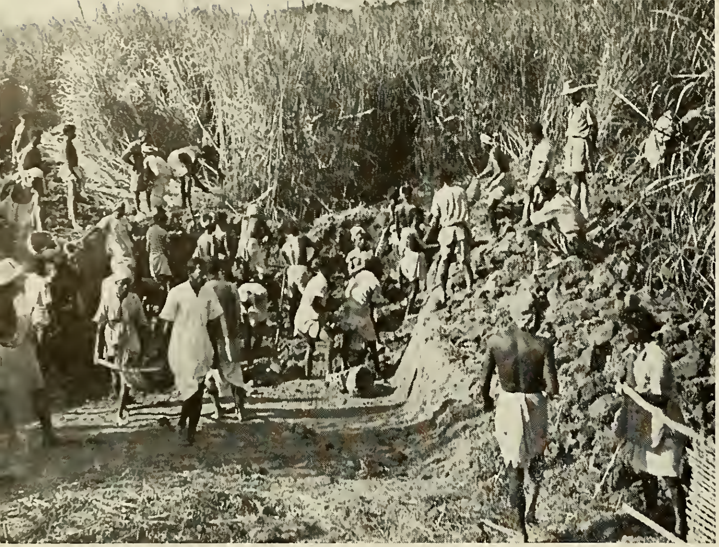
This article was written by Mr. Talbot, a doctoral candidate at the University of California, following a mission he undertook for the UNESCO-sponsored International Union for Conservation, on which he surveyed the status of the world's most threatened animal species. Photographs are by Kenn Reed, except for those on pages 559 and 561, which the author took while he was in India.



Cattle egret eats the insects that collect on rhino's hide, also warns the weak-sighted beast of approaching danger.

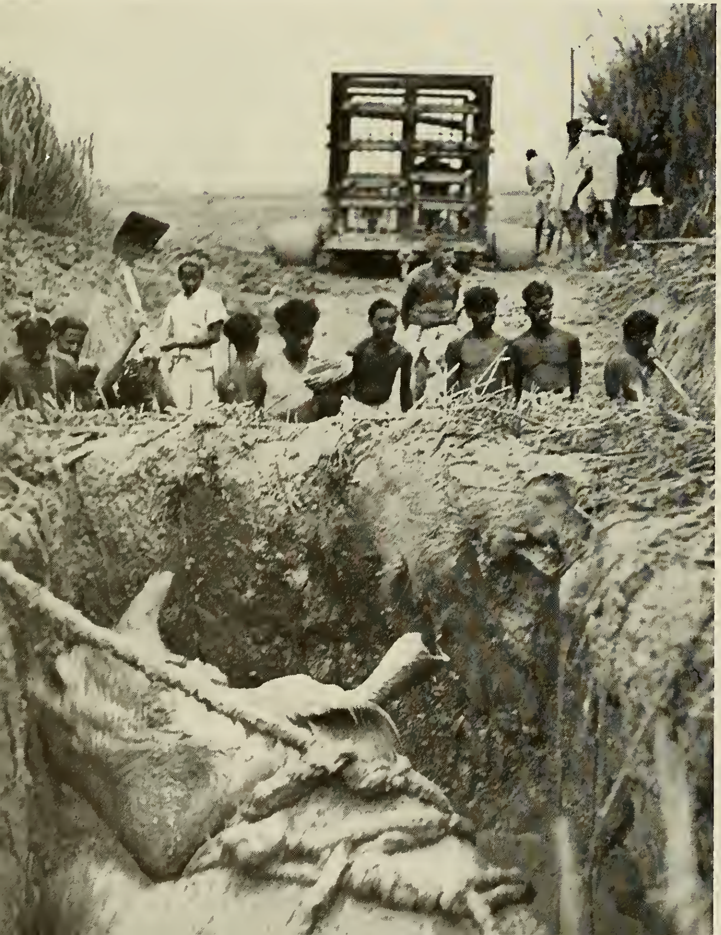
Alerted rhino senses alien presence of man and pauses to peer myopically about before emerging from mud wallow.





Laborers dig a path that gradually deepens, *above*, to six-foot level of pit, into which the rhinoceros blundered.

Last of earth between beast and man is hacked away, *below*, as cage, with door opened, is brought into position.



The skin is hairless, except for a fringe on the ears and tail and. as with other rhinos. the observed color usually is determined by the mud of its most recent wallow. A clean specimen is brownish gray, with a very slightly pink or reddish tinge at the edges of the skin folds, ears, and nostrils. The single horn is thick and usually blunt; it may reach two feet in length, but probably averages a little over one foot.

The Indian rhino's horn apparently is little used in combat. It is relatively soft, and grows from the skin as do hair and fingernails. It is not even very firmly attached to the animal's skull and a heavy blow can loosen or even rip it off. In fighting, this rhino uses its teeth, two long, sharp, lower incisors, with which it bites or rips much like a wild boar. With these it can inflict considerable damage, even on elephants. Thus a factual basis underlies Polo's seemingly fanciful statement that unicorns "... do no harm with the horn, however, but only with the tongue, for this is covered with long hard thorns and when the unicorns are angry they hold their victim under their knees and grate him...."

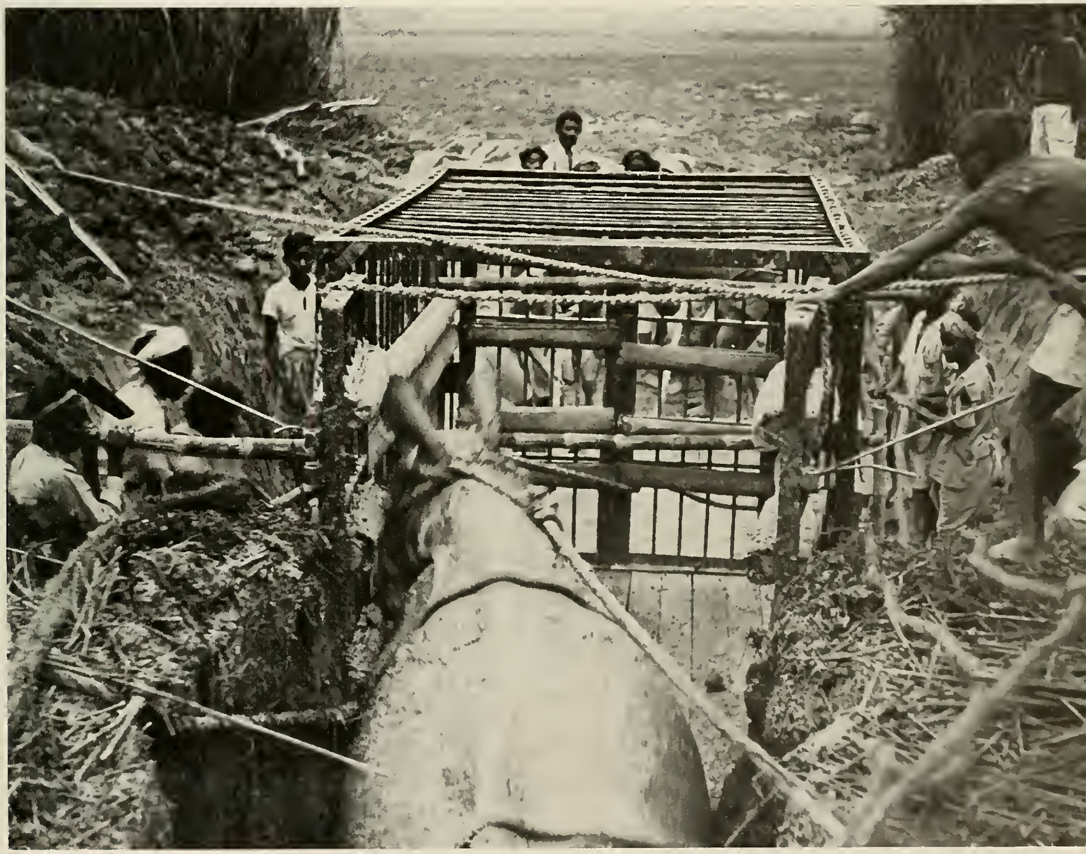
Rhinos are vegetarians. They feed both day and night, eating grasses, water weeds, leaves and twigs. Much of their time is spent in a mud wallow, especially during hot weather. In spite of its armor-plated appearance, rhino hide is quite sensitive. A relatively slight scratch will draw blood, and the wallows may serve to allay both sunburn and the attacks of insects that inhabit the wet areas where rhinos are found.

Water buffalo, gaur, various deer, wild pigs, and other animals may be seen peacefully feeding near rhinos. the pigs sometimes even sharing the same wallow. This tolerance does not extend to elephants, however. Rhinos and wild elephants apparently try to avoid each other; and most domestic elephants are terrified of rhinos, refusing to approach them closely and occasionally even bolting at the sight of them. Myna birds and cattle egrets are the rhinos' virtually constant companions, often riding their backs and providing an early warning system for the rather weak-sighted beasts. Aside from man, the tiger is probably the only predator the rhinos need fear, and the latter kill only rhino young.

Marco Polo also mentioned unicorns in Burma and western India. In his time, the westerly boundaries of the Indian rhino's range were the foothills of the Hindu Kush, near the Khyber Pass, and the bush country south along the Indus River. The northern limit was the frontier of Kashmir and the foothills of the Himalayas. The southern and eastern boundaries are uncertain. Indian rhinos were certainly found as far south as the Bay of Bengal and as far east as Burma. They may have ranged all the way to the shores of the China Sea, for one-horned rhinos have been reported from Malaya, Thailand, Indochina and south China. But these reports may refer to the smaller, Javan rhinoceros. In any case, in Polo's time, the Indian rhino ranged much of the Indian subcontinent and, possibly, southeast Asia.

By 1900, the Indian rhino's range had shrunk to two valleys at the foot of the Himalayas. At that date, the last rhinos known to be in India were scattered in about a dozen isolated pockets along the Brahmaputra River in Assam and Bengal, and the largest single known population was estimated at twelve animals. An additional rhino population, of unknown numbers, lived in the Chitwan Royal Hunting Preserve, in the remote Rapti Valley of the Kingdom of Nepal. Hunting and habitat encroachment had brought about this drastic cut in a once widespread population.

But the rhino's greatest misfortune is that he carries a fortune on his nose. Since very early times, "unicorn" horn has been credited with marvelous medicinal and magical properties. Drinking vessels made from it supposedly rendered poison harmless, and thus were standard equipment for numerous Eastern and Western rulers until quite recent times. Properly prepared and applied, potions of rhino horn were believed to aid recovery from wounds or sickness, to reduce pain, ease childbirth, and to possess rejuvenating powers. These beliefs also extended to every other part of the animal's body and its bodily products. So great has the faith in these qualities remained in the Orient that prices as high as $2,000 have been offered for a single horn, and a poacher could make the equivalent of several years' normal wages from one whole rhino. Considering all this, the wonder is not that rhinos were rare by 1900 but that they still existed at all. And yet,



Confining ropes, which have kept the animal from breaking for freedom, are now slacked and the rhinoceros, following its only possible course of action, moves directly into the cage as Indian trappers and workmen watch apprehensively.

important as was hunting pressure in reducing the rhinos, it was probably only a coup de grâce to a population already in desperate straits.

As the human population of India increased, so did the amount of land occupied by villages or used for cultivation and grazing. In the six hundred years following Polo's travels, much of the northwestern part of the rhino's range in India had become increasingly arid and untenable as rhinoceros habitat, largely because of population pressure and land abuse.

As the fertile lowlands were taken over for agriculture, the rhinos retreated to the sparsely inhabited hills. To this area they were followed by different varieties of agriculture (largely rice and tea), by grazing livestock, more intensive land use and, of course, more people. Even where their range was not actually converted to agriculture, the rhinos were deprived of food and cover, and became easier targets for poachers. It was a vicious cycle: as the rhinos became scarcer, their individual value increased and, with it, the poaching pressure.

The rhino population was so reduced by the early 1900's that the British authorities became alarmed. They declared the animals legally protected and established a series of small sanctuaries and reserves in Assam and Bengal, designed to protect both the last concentrations of the rhinos and some portion of their habitat. By the 1930's, rhino products had become so valuable that poaching became an organized business, and troops were called out to fight the poachers and protect the rhinos. During World War II, poaching slacked off.

Following the war, and especially after Indian independence, there was a renewed interest in wildlife conservation in Assam, sparked by two men: E. P. Gee, a British tea planter long interested in the rhinos, and Assam's Conservator of Forests, P. D. Stracey, under whose jurisdiction fell such wildlife matters.

The rhino population in India today has increased to some four hundred animals, all but a dozen or so living in the protection of eight reserves in Assam and Bengal. Another four to five hundred animals may survive in the Rapti Valley. However, recent information from the International Union for Conservation indicates that the latter population may have been virtually wiped out by poachers within the last year.

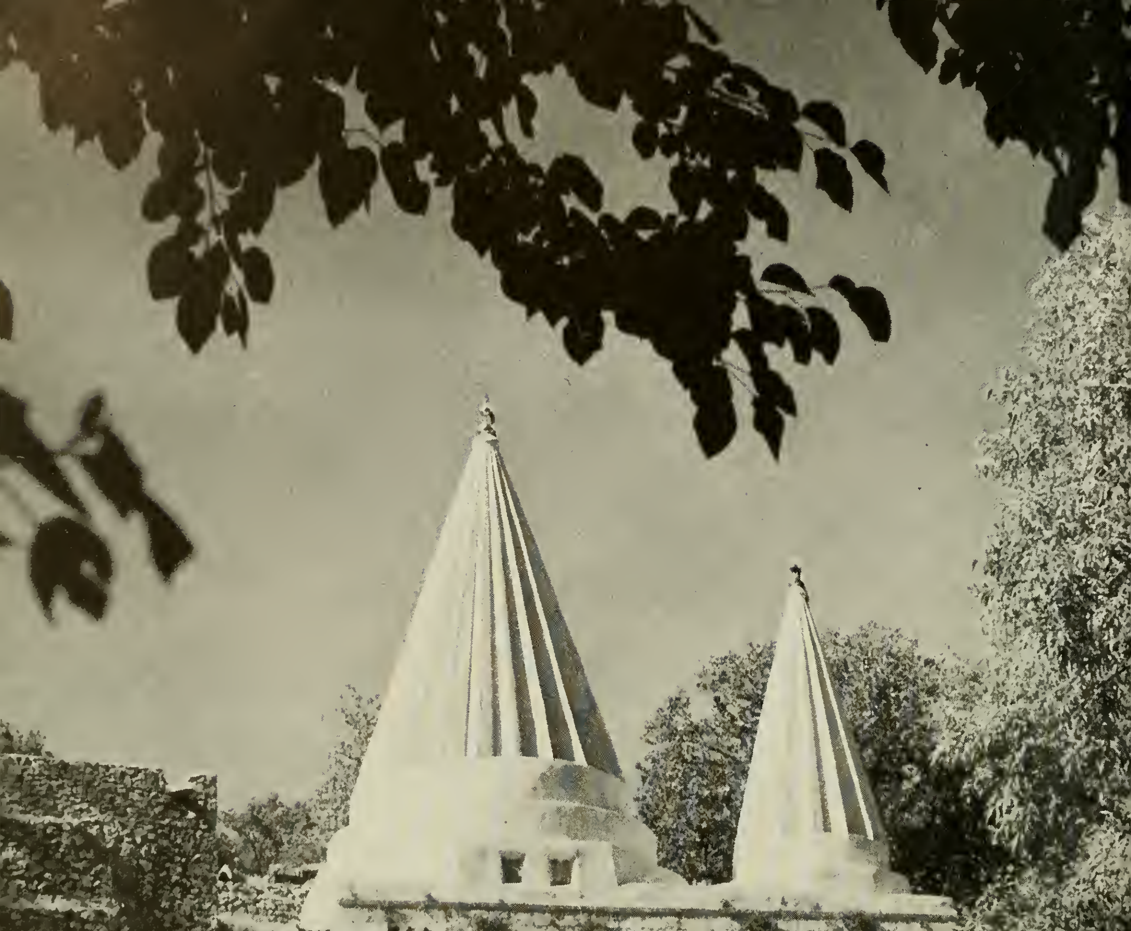
The Indian rhinos in India, on the other hand, are well protected for the time being against either poaching or threat to their habitat. Some two hundred fifty are in the magnificent Kaziranga Wildlife Sanctuary, in Assam, a wide expanse of elephant grass plain, cut by waterways and low, wooded ridges. Here the government provides facilities for visitors who wish to stay and view the rhinos from elephant-back, and there is a staff of about fifty persons to maintain and protect the area. The rhino population here appears to be increasing and the government has permitted a very few animals to be caught, under close supervision, for shipment to approved foreign zoos.

PROBABLY the greatest immediate threat to the Indian rhinos' future is the constant pressure to open the reserves so that their fishing, grazing, and agricultural possibilities may be exploited. Fishing and grazing are both allowed in the Sanctuary on a limited basis, making the threat of disease transmittible from domestic stock, a very constant menace to the rhinos and other wildlife. However, in 1956, as a consequence of the effective protection provided by the Indian Government, the Survival Service of the International Union for Conservation removed the great Indian rhinoceros from its list of "Fossils of Tomorrow"—a roster of the world's most critically threatened species—and placed the rhinos instead on its provisional list.

Although, at present, those rhinos in the Indian reserves are holding their own or increasing, their future is still far from assured. The greatest immediate need is a sound knowledge of the animal's ecology—its habitat web. Without such information on which to base effective management, no animal's survival can be assured. Unfortunately, the Indian rhino has yet to be the subject of intensive, scientific investigation: we know little more now about its ecology than did Marco Polo in 1298.

STOCKADE, *left,* is rhino's home until it has adjusted to state of captivity.

WITHIN A WEEK of capture, the once-fierce rhinoceros has accepted its fate, and will take proffered food from hands of its keepers. After a few more weeks in the stockade, the animal is considered ready for shipment to some foreign zoo.



Gilded ornaments gleam from the pinnacles of Sheikh Adi's shrine in the Lalesh Valley. Conical spires are typical of Yezidi architecture, and decorate several temples. Spires are made by setting a tall pole in the middle of a circular base. Several supporting rods run from apex of central pole to base's rim. Entire spire is then gessoed and whitewashed.

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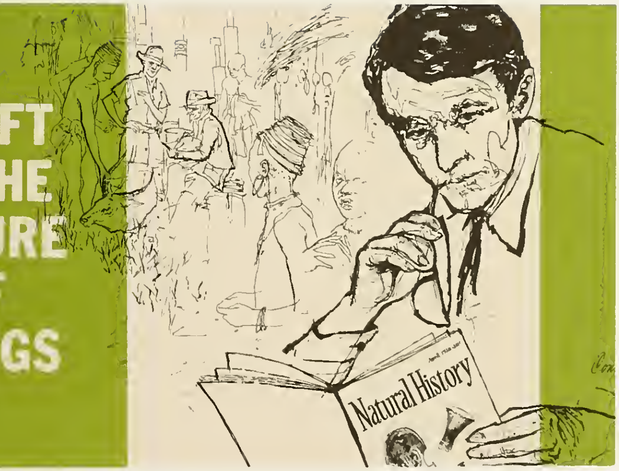
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THE PEOPLE OF THE PEACOCK ANGEL

A Kurdish sect in the hills of Iraq claims that Satan has been forgiven

By L. P. Harvey

Yezidi priest kisses stone at temple door. Rock is revered because earliest rays of the sun shine on it each day.

The communities of Yezidis who inhabit various inaccessible mountainous regions of the Middle East for long constituted an insoluble mystery to the outside world. Their name, they do not deny, links them with the Ummayyad Caliph, Yezid I (d. A.D. 683), one of the most execrated rulers in the whole of Moslem history. That they should be called Yezidis is as if, in a Christian context, a sect traced its origins to Judas Iscariot or to Pontius Pilate. Yet this is one of the more polite names for them. "Devil-worshipers" is more common, and even *chiragh söndiren* (those who douse the lights), in allusion to the scandalous story that, at their festivals, after the devotees have worked themselves up to a pitch of frenzy with chants and dancing, the lamps are extinguished and anything goes.

Who are these people? What are their true beliefs, and how did they come to hold them?

As to who they are, Yezidis are all Kurdish-speaking. Some live in parts of Syria and the Russian Caucasus, but their chief centers are in Iraq—north and northwest of Mosul in the Jebel Sinjar and the region of Shaikhan. There, set in the valleys of Lalesh—some forty miles north of Mosul—lies the most holy of all Yezidi shrines, the tomb of Sheikh Adi (photograph, *left*).

Yezidi society is divided into four endogamous classes: these are, in order, *Sheikhs, pirs, feqirs,* and *murids.* Each sheikh has in his charge a number of the laity, who contribute offerings in return for his ministrations. A family with special prestige is that descended from Sheikh Hasan, who have charge of the Yezidi scriptures, *The Revelation* and *The Black Book.* From their number, *peshimams*—district religious leaders—are chosen, and their presence at a wedding is held to be a blessing.

The *pirs,* next in rank, are the Yezidi equivalent of lesser clergy. They also have their part to play in religious ceremonies, but their prestige is not as great as the sheikhs', and their income from alms correspondingly smaller.

The third class, the *feqirs,* wear a very distinctive dress, a tunic *(khirqa)* of black wool falling tight to the knees, and gathered in by a girdle. The *khirqa* is the sign that its wearer has been fully initiated into the order, for a *feqir* is not born into membership of his caste, but must be ordained when an adult. The *feqir* has no special public functions but he is regarded with particular awe by the rest of the community. Unseemly behavior must stop in his presence. He should fast much longer than other Yezidis, some say ninety-two days as against an ordinary man's six. Although these are lax times, the *fequirs* continue to demand privileges that must originally have been given as rewards for such ascetic practices: For example, the right to requisition whatever goods they need.

The common people of the Yezidi are termed *murids.* From them little religious knowledge is expected. Indeed, the average Yezidi has only the most confused notions about his religion. His fasts are limited to two periods of three days each year: other ritual demands are similarly slight. Yet in a sense the whole of his life is bound up in his religion.

The *murid* has five primary obligations: he must have a Lord—*usta*—(i.e. God): a *sheikh,* a *pir,* a "brother of the next world"; and a "tutor." The *murid* cannot choose his *sheikh* or his *pir,* but he can freely choose for him-

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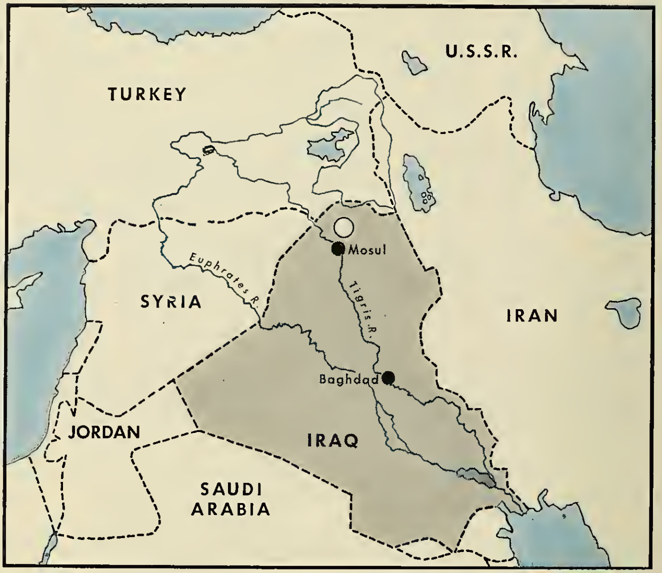
self a *sheikh* to be his brother of the next world, and a *pir* to be his tutor. The brother of the next world performs a function similar to that of the Christian godfather, but the link is much closer. Every day the *murid* should go to his "brother" and kiss his hand. The brother plays an essential part at a Yezidi wedding, and at every stage in a Yezidi's life until his dying hour. The tutor's function is to instruct the *murid* in his religious obligations. Thus the whole of Yezidi society, although split into caste groups, is bound together again by these links across caste barriers.

Ruler of the Yezidis is the Emir, a man of sheikhly family who claims descent from Caliph Yezid I. He is usually described as a secular leader, as distinguished from a religious head of the Yezidi, but such a clear distinction is rather misleading. The Emir's political authority does not extend beyond the region of Shaikhan and, if he has prestige much further afield, this is due to his control over the shrine of Sheikh Adi, and over the sacred peacock images (*sanjaqs*) which he can authorize to be taken on tour of distant areas.

The shrine of Sheikh Adi—shown in the pictures on these pages—is thus a center of both religious and political influences. In this vicinity are found the *qawwals* (literally, "chanters") who form a guild of sacred minstrels, trained in religious lore. They play on the pipes and tambourine in the ceremonies at Sheikh Adi. But more important must be the role of the *qawwals* as links between the central shrine and the scattered outposts of Yezidism up and down the Middle East. For it is they who exhibit the sacred peacock images in distant villages, and act as couriers and channels of information. Modern passport controls hamper their movements, and the revenues of the central Yezidi authorities must have suffered accordingly, for the Emir arranges to sell the privilege of parading the images to each *qawwal*, who in turn sells the privilege of lodging the peripatetic peacock images to the highest bidder



LALESH VALLEY, north of Mosul, Iraq, *above*, is religious center for Yezidis.

FORELOCKS of urchins, *below*, will be used by angels to draw them to heaven.

PILGRIMS, *right*, climb barefoot to their most holy shrine of Sheikh Adi. Water flows down the steps from a sacred well and, it is believed, purifies the faithful.

Pilgrims to shrine are enthralled by performance of the snake charmer, whose act at once attracts and repels. Man holds snake near his face, *above*. Then, with snap of his jaws, he bites off head, *below*, as watchers recoil, *right*.

in each village he visits. This is perhaps to put too mercenary a coloring on the transaction. By all accounts the cry, *Sanjaq hat*—"The image has come" — is a sign for sincere rejoicing everywhere in Yezidi lands.

The *ferrash* or sacristan of the sanctuary of Sheikh Adi (photo, p. 574) is also involved in the monetary side of religion. He is appointed on a yearly basis, and pays a considerable sum (about $1,000 in 1940) for the honor. But he can hope to recoup his fee — and more — from visitors' alms. His main duty is to tend the many oil lamps and, as he goes on his rounds, he offers the sacred flame to all pilgrims. They pass their hands through the flame and over their faces in a gesture which would seem to symbolize purification by fire.

WHAT do the Yezidis believe? The heart of their cult is secret, and it is difficult to give a systematic account of their theology. Nothing suggests that the scandalous orgies of which they are popularly accused do in fact take place. But do they really worship the Devil? The answer is both "yes" and "no."

To them God (*khode*) may be Almighty, but He keeps Himself withdrawn from the affairs of the world. So it is the first of His angels, Malak Ta'us, the Peacock Angel (otherwise Azazil — the Arabic name of Satan before his fall), who is the center of their worship. The names of the *fallen* Satan (Shaitan or Iblis) are taboo to all Yezidis and it is even said that if a Yezidi hears anyone "taking the name of Satan in vain," he has an obligation to put the blasphemer to death.

If this be so, Sir Austen Layard had a narrow escape when he witnessed the pilgrimage to Sheikh Adi in 1846. The crowds were so dense that some children climbed trees to get a better view. One urchin on a weak branch seemed about to fall:

"As I looked up I saw the impending danger, and made an effort, by appealing to the Chief, to avert it. 'If that young Shait . . .' I exclaimed, about to use an epithet generally given in the East to such adventurous youths. I checked myself immediately, but it was already too late. Half the dreaded word had escaped. The effect was instantaneous. . . . The pleasant smile which usually played upon the fine features of the young Bey gave way to a serious and angry expression. . . ."

TAMBOURINE for young male dancers is played by a *qawwal*, one of the sacred minstrels who link far-flung Yezidis by acting as reporters and couriers.

Fortunately for Sir Austen, he was there as an honored guest, and the slip of the tongue was forgiven.

There is, then, no doubt that Malak Ta'us is reverenced, but is he really the Devil? To Christians and Moslems, Satan is the Fallen Angel, damned for disobedience. According to Yezidi doctrine, on the contrary, the Devil has been pardoned, and has regained his former leading position. The fires of Hell have long been extinguished. Evil can no longer be regarded as the result of something which has gone wrong in the proper order of things: if it still exists, it is because evil is an inescapable part of that order. The resultant world-picture is a very pessimistic one, but it accords with what the Yezidis know of history.

IN spite of many outward aspects which proclaim Yezidism's Islamic origins, beneath lie substrata that include Christian, gnostic, Iranian, and purely pagan beliefs. For example, Yezidis make the Sufi saint, Shams-addin, the patron of their worship of the sun (Arabic *shams*). It is to the sun that they face during prayers: every morning they should kiss the object on which the first rays of the sun are

Qawwals pay for privilege of showing peacock images in villages they travel through. In turn, they may charge the faithful for honor of housing images.

seen to fall. Yezidism is, in fact, one of the most fantastic examples of religious syncretism known.

In what circumstances could such an imperfectly assorted collection of doctrines have been assembled? Yezidism is the reaction of certain groups of Kurds against the Arab-dominated majority religion, Islam. Paradoxically, they asserted their Kurdishness by professing allegiance to the cause of an Arab Caliph, Yezid, and an Arab Sufi, Sheikh Adi. In earlier times, Yezid and the Ummayyad cause provided a potential rallying cry for dissident extremists, but it was not until Adi (b. A.D. 1075 in Syria) came to Lalesh that Yezidism, as we know it, began to take shape.

Yet Adi was a very orthodox Sufi, who had retired to these Kurdish hills to meditate. When, in the way of the East, the holy man gained a following, their excessive devotion worried him. In vain did he eat before them to prove he needed food like any man: they persisted in attributing all manner of miracles to him.

Before Adi's arrival in Lalesh, the Nestorian Christian monastery of Jesus Our Hope stood where the Yezidi temple is now. Adi and his nephew — who succeeded him — seem to have lived amicably with the monks. But the next Sheikh of the Sufi order founded by Adi (the *Adawiyya*) took advantage of the troubled times to seize the monastery and put the monks to the sword in the year 1219.

It was to the Mongol hordes of Genghis Khan — then occupying the neighborhood — that the Christians appealed for justice. The Sheikh was arrested and executed in 1221, but his family clung on to Lalesh in defiance of restitution orders granted to the monks. Finally one of the Adi family — who had had the good sense to take a Mongol wife — was confirmed in possession of the property.

All this time the Kurdish tribesmen were gradually imposing their own patterns of belief on the Islamic sect of the *Adawiyya*, transforming it into heresy. How this took place is best illustrated by the story told of a later Sheikh, Hasan ibn Adi Shams-ad-din — whose sonorous name shows his distinguished lineage. One day a visiting preacher addressed Sheikh Hasan and his rude Kurdish followers so eloquently that Hasan was moved to tears, and finally fainted away. When he recovered, he was horrified to find the preacher dead at his feet, covered in gore. Asked what had happened, the Kurds replied that they had put him to death: "Who did the dog think he was, to make our Sheikh weep?" And, we are told, Sheikh Hasan did not dare rebuke them.

Here is the beginning of the process which rapidly bore Sheikh Hasan up into the Yezidi pantheon as the second of the seven angels whom God created in the Beginning. The succession of Sheikhs seems to have struggled to check the worship accorded them, but eventually some must have yielded to the temptations of power, and so the family of erstwhile Syrian ascetics found itself at the head of a sect of wild Kurdish mountaineers.

History thus gives us a possible explanation of the modern Yezidi caste-names. The *shiekhs* (Arab name) may be the descendants of those who came with Adi from Syria (this would account for the Semitic physical type noted as frequent among them). Those who are known by the Iranian term *pir* may be the descendants of their principal Kurdish disciples, while the *feqirs* and *murids* represent the mass of the tribesmen.

TEMPLE, *above*, is on site of ancient Christian monastery. Snake carving at doorway has no religious significance.

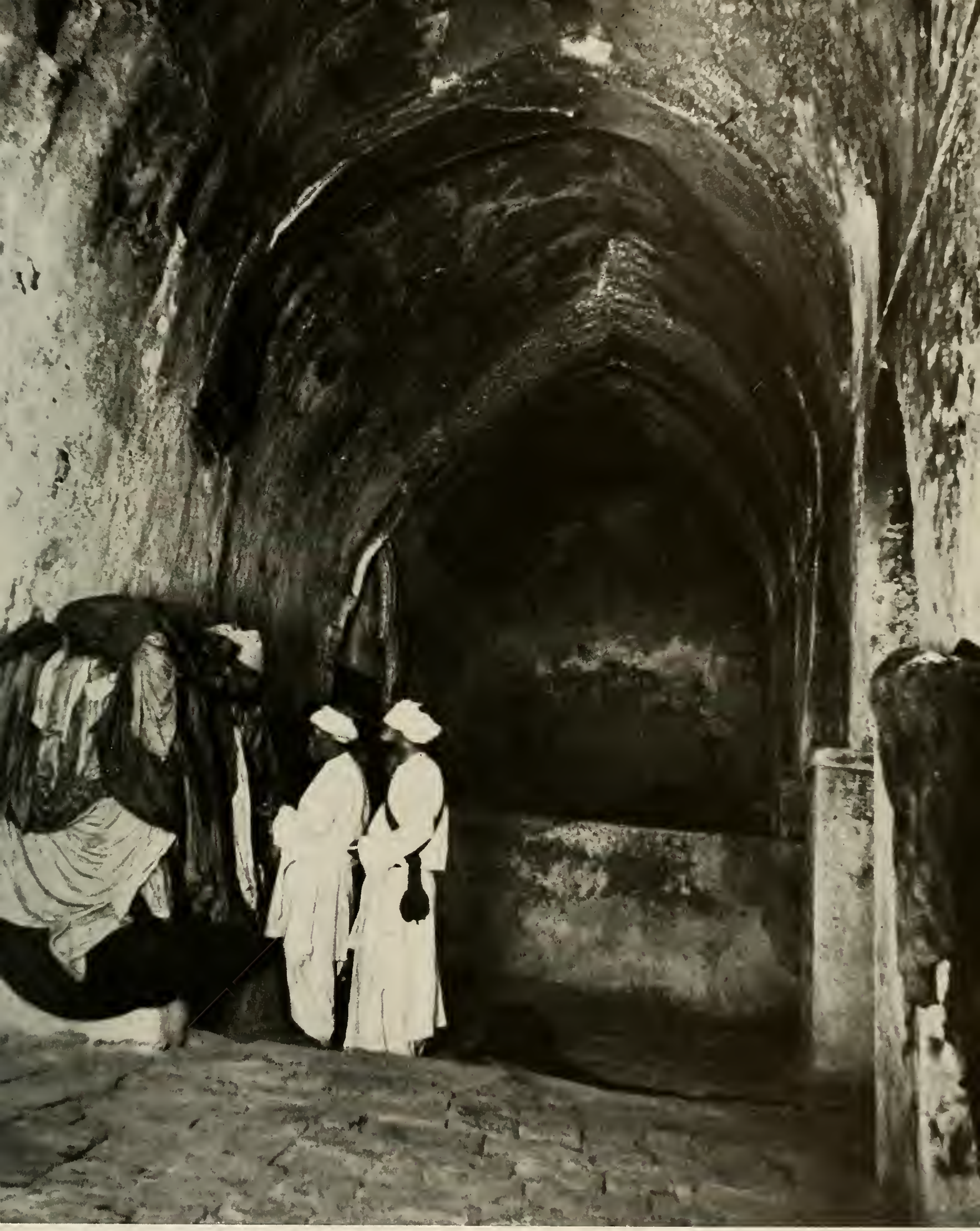
SACRISTAN at Sheikh Adi's shrine is in charge of temple's oil lamps, which are lighted by the sacred flame, *above*.

WORSHIPERS must step over, not on, threshold, *below*. Priest and son enter to worship at shrine of Peacock Angel.

The growing heresy of Adi's followers brought them the enmity of their neighbors. Their history is a long list of massacres and persecutions. As recently as 1892, the shrine of Sheikh Adi was occupied by Turkish troops in the course of a campaign in which Yezidis were offered the abrupt alternatives of conversion or death.

It is probably as a reaction to such pressures brought to bear from outside, that the Yezidis over the centuries have come to emphasize the more bizarre aspects of their creed. History may show that the roots of Yezidism lie in Islam, but the modern Yezidi is in no way conscious of this, any more than the average Christian is aware of the pre-Christian rites that lie behind his Christmas holiday. The Yezidis now form a tight little community apart. Their worship of the Peacock Angel, coupled with their numerous taboos, makes it extremely difficult for them to mingle with outsiders.

What can be their fate in the modern world, which has little patience with such eccentricities? Yezidism has only survived as long as it has because of its isolation. Whether the sect can survive the coming of the government schoolmaster, the recruiting sergeant, the newspaper and the radio, must remain an open question.



Sheikh Adi's shrine, traditionally covered with drapes, stands in "side chapel" off a large, columned central hall that may have been the original nave of Nestorian church that once stood on the site. Gothic arches attest to the Christian sources of the building. Also in this temple is a smaller shrine holding the image of the Peacock Angel.

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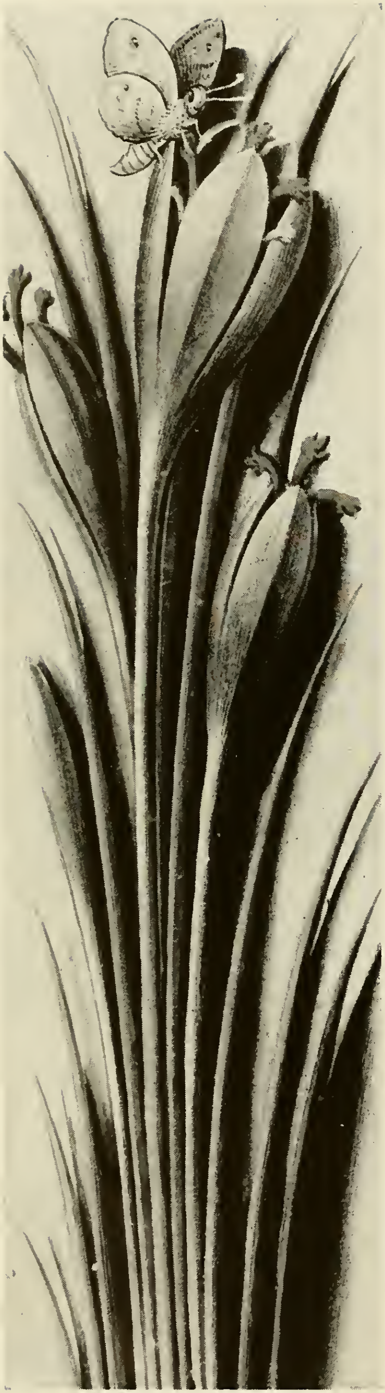


saffron crocus

the roots
ancient

The lore of medicinal plants

In November of 1492, a few weeks after Columbus made his celebrated landfall at San Salvador, a French court miniaturist, Jean Bourdichon, was paid fifty livres tournois by Queen Anne of Brittany for copying and illustrating on vellum a prayerbook of the sort known as a Book of Hours. A Book of Hours was essentially a text work, but the patrons who commissioned them—each a person rich enough to afford the work of copyists and illuminators—probably cared at least as much for the decorations as for the prayers.

For many centuries, the flowers that had found their way into Christian symbolism had been used to decorate such pious works. Jean Bourdichon, however, did not limit himself to these flowers as decoration for Queen Anne's book. It is of interest to speculate on his reasons. Born about 1458, he died sometime before 1521, an era in which the art of the illuminated manuscript was drawing to its end. Printing had already spread from Mainz to many parts of Europe and with it, among other things, had spread a tremendous interest in medical botany—a study that had been dormant for centuries.

Long after the decline of Greece and Rome, the study of plants—which had passed into Syria in the time of Alexander—flourished in the Near East. There, early plant books from classical sources were translated into Arabic and kept alive during Europe's Dark Ages. At the beginning of the Renaissance, these works were once again translated into Western tongues and the translations, aided by printing and the resulting compendia of medical information

# of healing-herbals

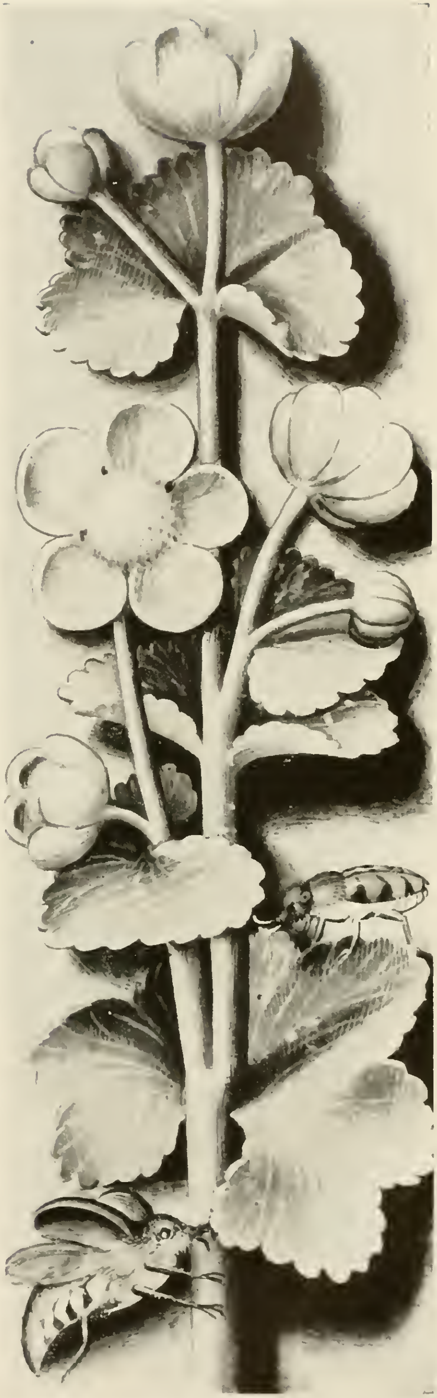
gave modern botany its start

known as herbals, brought about the Western revival of medical botany.

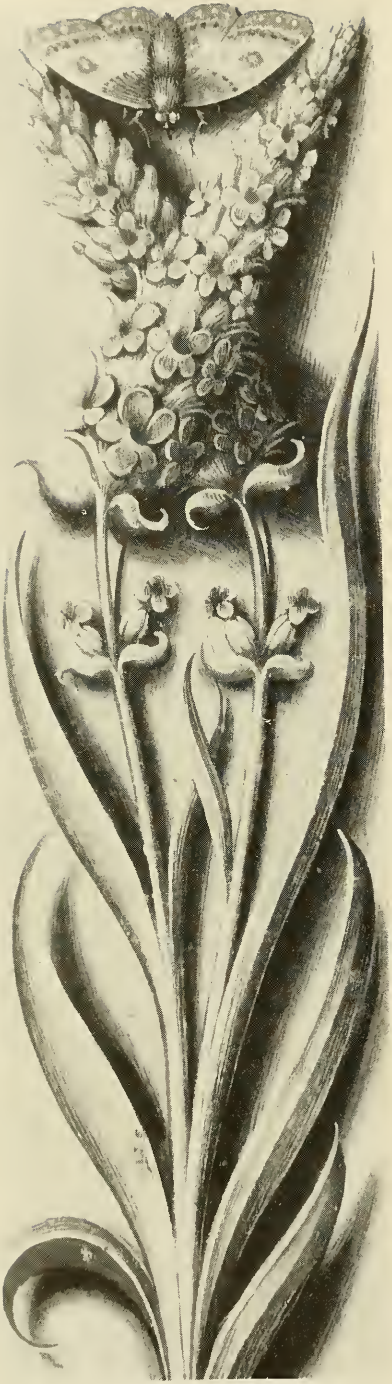
Much of the information in these early European herbals dated back to the first century A.D., when Dioscorides, a physician to the Roman army who traveled with the legions and collected information on plants in every country he visited, penned his epic *De materia medica libri quinque*. This book, copied again and again, was virtually the only medical reference of its sort known for sixteen centuries. By about the fifth century A.D., plant drawings came to be included in copies of the Dioscorides manuscript. Many printed Renaissance herbals, in turn, used crude wood-block adaptations of these pictures, instead of original art work.

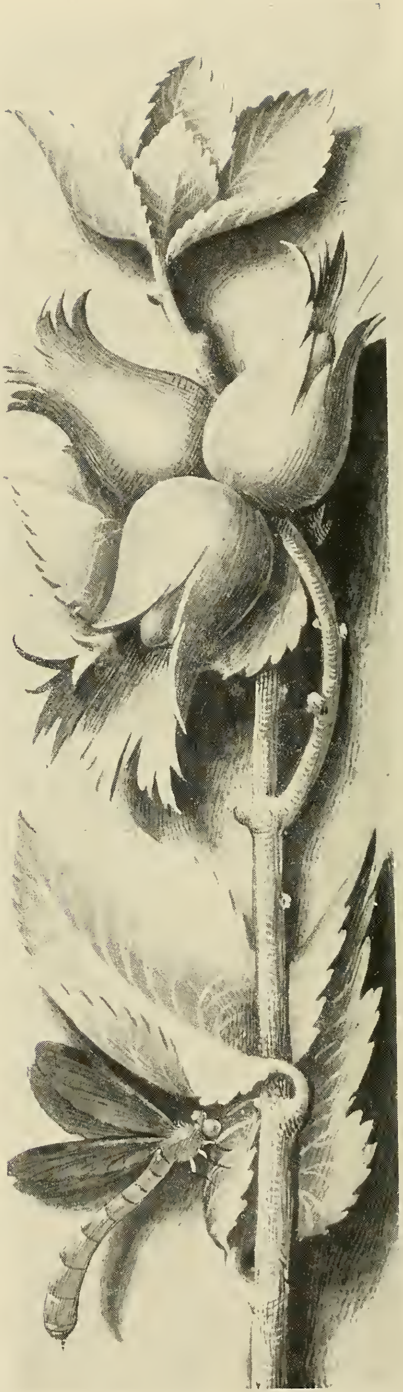
To depart from symbolism alone and to include samples of this rediscovered learning may have been Bourdichon's motivation in 1492. In any case, his paintings were unequaled in beauty and botanical accuracy except, perhaps, by the work of his contemporaries, Albrecht Dürer and Leonardo da Vinci. Bourdichon coupled careful observation with an evident enthusiasm for the new world of botany. The paintings in his manuscripts include flowers and fruits of plants that figured in the herbals of the period as possessing specialized household, culinary, or medical value.

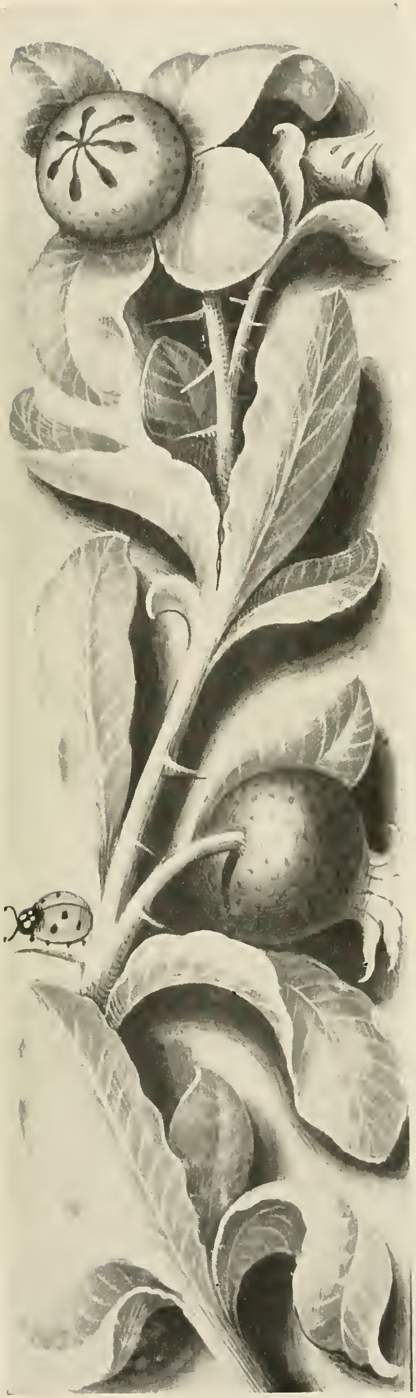
On these two pages, for instance, are the saffron crocus, *left*, and the marsh marigold, *right*. Use of the former dates from earliest antiquity. Saffron—as a flavoring, a dye, or a medicine—is made from the dried stigmas of



marsh marigold


french lavender


filbert nut



medlar tree

this flower. Its first mention is medical: a 1552 B.C. Egyptian papyrus recommends it for inflamed eyes. The Greeks considered the yellow of saffron to be a royal color. An early English recipe says: "For hen in broth, color it with saffron, for Goddes sake."

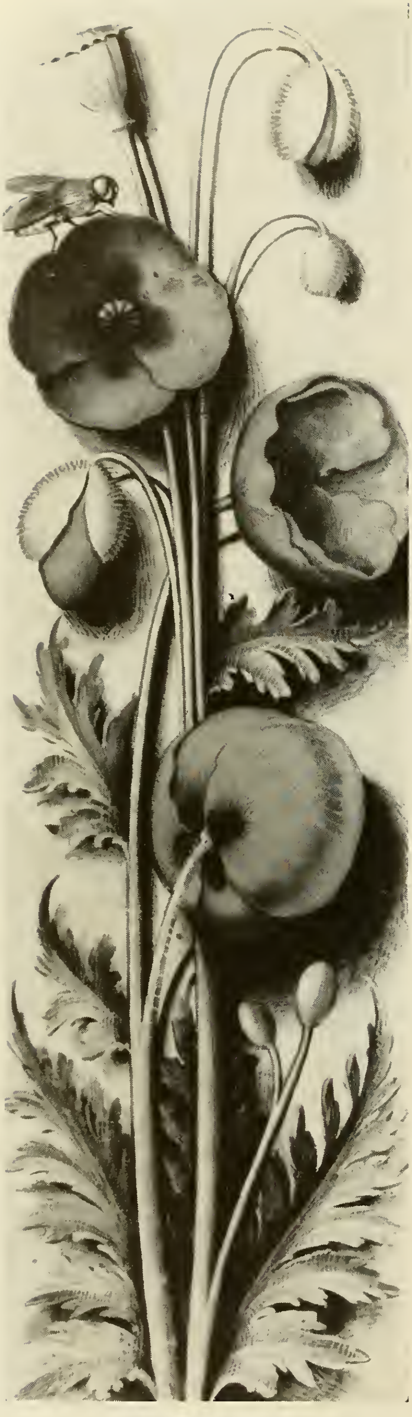
The marsh marigolds—that "ioy in moist and marish groundes, and in watery medowes" —were cautiously recommended by the herbalists as a remedy for toothache. Its flower buds have been used as substitutes for capers.

The importance of plants to Renaissance man was expressed in the famous sixteenth-century herbal compiled by John Gerard, in which he said: "The delight [in plants] is great, but the use greater, and ioyned often with necessitie. . . . [They are] of necessarie use both for meates to maintaine life, and for medicine to recover health." This dual function of plants manifests itself again and again in the literature of the period.

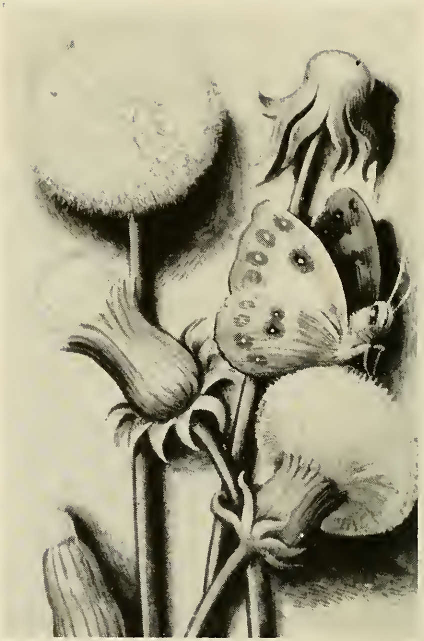
Thus, French lavender, *left,* while cultivated as a garden plant for its honey, was also valued as a remedy for headache, apoplexy, "falling sicknesse," and chest diseases. The filbert nut, *center,* while used as a food, was also pounded into a milk and prescribed for chills and fevers. The fruit of the medlar tree, *right,* looks and tastes rather like crab apples, and was popular as a preserve. Its kernels, however, were also powdered and administered as a diuretic.

The seeds of the garden poppy, *next page, left,* were used both in Europe and Asia to prevent scurvy and cure pleurisy, and its petals were a source of coloring matter.

During the French Revolution, parchment ran short and an appeal was made for contributions. Sixty years later, in 1850, amid an accumulation of vellum and parchment in a French arsenal, was found the book that contains these illustrations. Named the Holford Hours after an early owner, the book is now in the collection of The Pierpont Morgan Library in New York City, to which we extend thanks for the co-operation that made these reproductions possible. The book is a 1505 replica of Queen Anne's Book of Hours: like hers, it was executed by Jean Bourdichon. It contains ninety-four flower pictures on fifty-eight leaves, but over a third of the original manuscript is unfortunately missing.



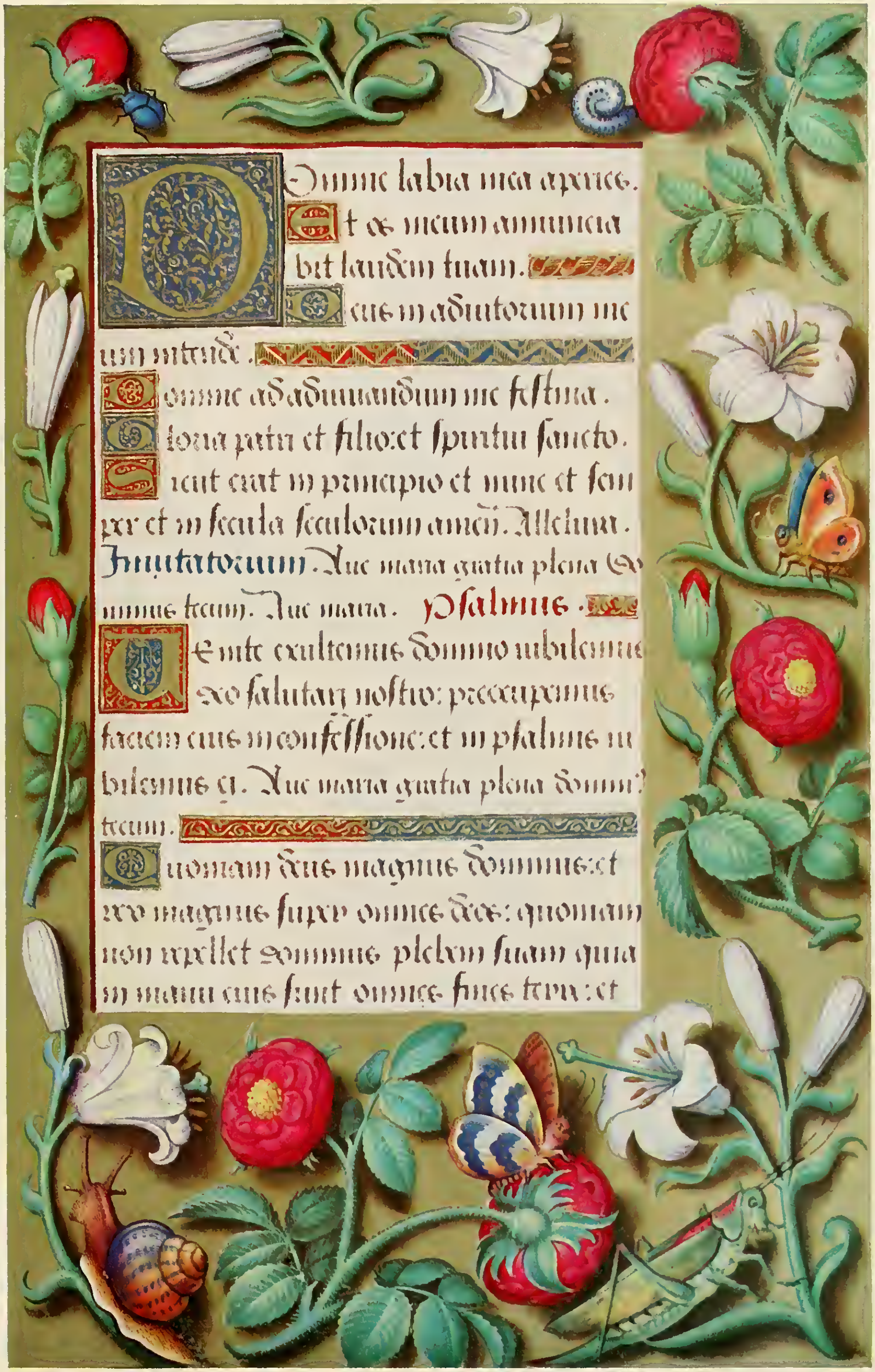
garden poppy



dandelion

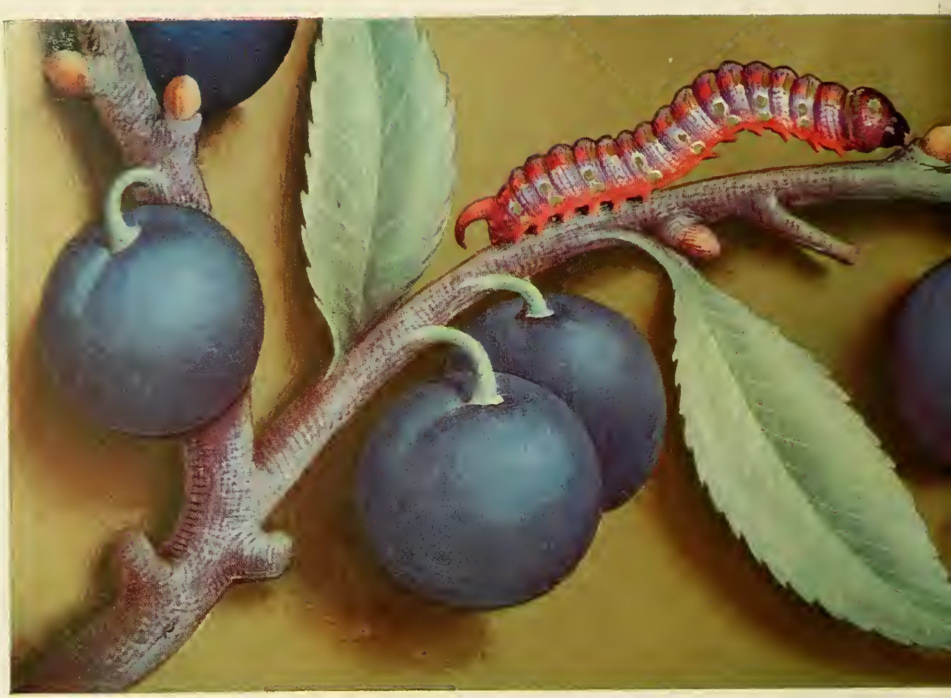
The dried rhizomes and roots of the dandelion, *above,* have been used for centuries for a multitude of medical purposes. Most popular as a "stomach cleanser," an infusion of the roots was also esteemed as a tonic. The dandelion has enjoyed a popularity in the kitchen for many years, too. Its leaves have been cooked and eaten like spinach, or blanched and put in salads. Its flowers, then as now, were made into a kind of tonic wine.

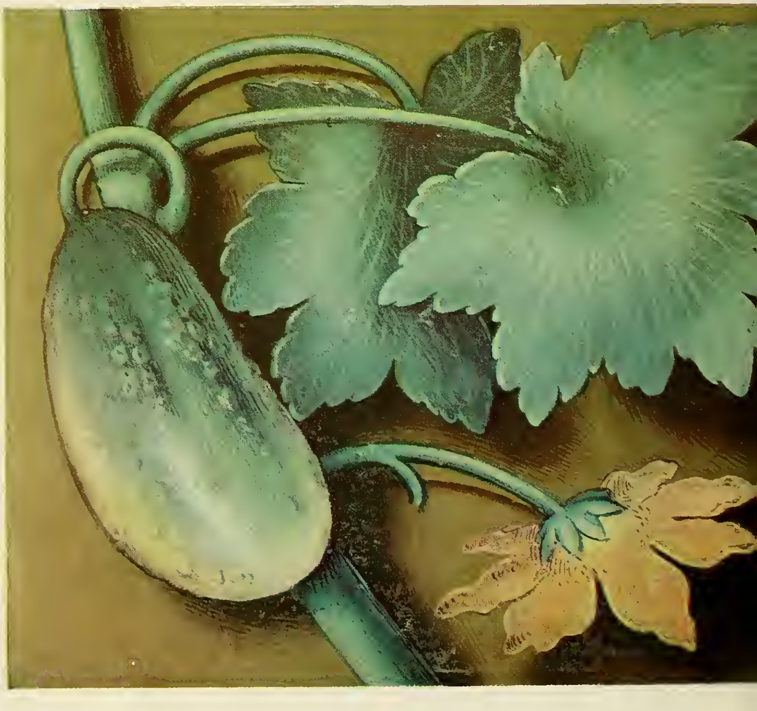
The rose and lily design, *opposite page,* is an excellent example of the way in which pagan beliefs became part of the Christian symbolism. The rose was a flower sacred to Aphrodite and, later, to Venus, the Greek and Roman goddesses of love. By the fifteenth century A.D., the flower was associated with the Virgin, and represented divine love. The lily, in ancient Crete, was the flower of fertility. In the Christian context, it came to stand for chastity. These two, combined, became a symbol for the Virgin birth. From the earliest times, these revered flowers were also used medically—the rose for eye and heart ailments, the lily root for burns and its juice for snake bite.



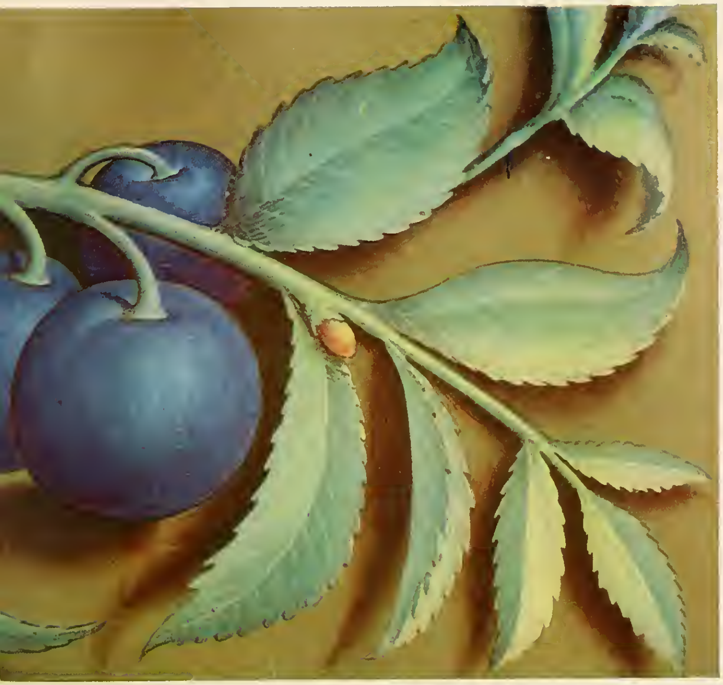
Domine labia mea aperies. Et os meum annunciabit laudem tuam. Deus in adiutorium meum intende. Domine ad adiuvandum me feſtina. Gloria patri et filio: et ſpiritui ſancto. Sicut erat in principio et nunc et ſemper et in ſecula ſeculorum amen. Alleluia. Invitatorium. Ave maria gratia plena Dominus tecum. Ave maria. Pſalmus. Venite exultemus domino iubilemus deo ſalutari noſtro: preoccupemus faciem eius in confeſſione: et in pſalmis iubilemus ei. Ave maria gratia plena dominus tecum. Quoniam deus magnus dominus: et rex magnus ſuper omnes deos: quoniam non repellet dominus plebem ſuam quia in manu eius ſunt omnes fines terre: et

rose and lily design edged page in book of hours

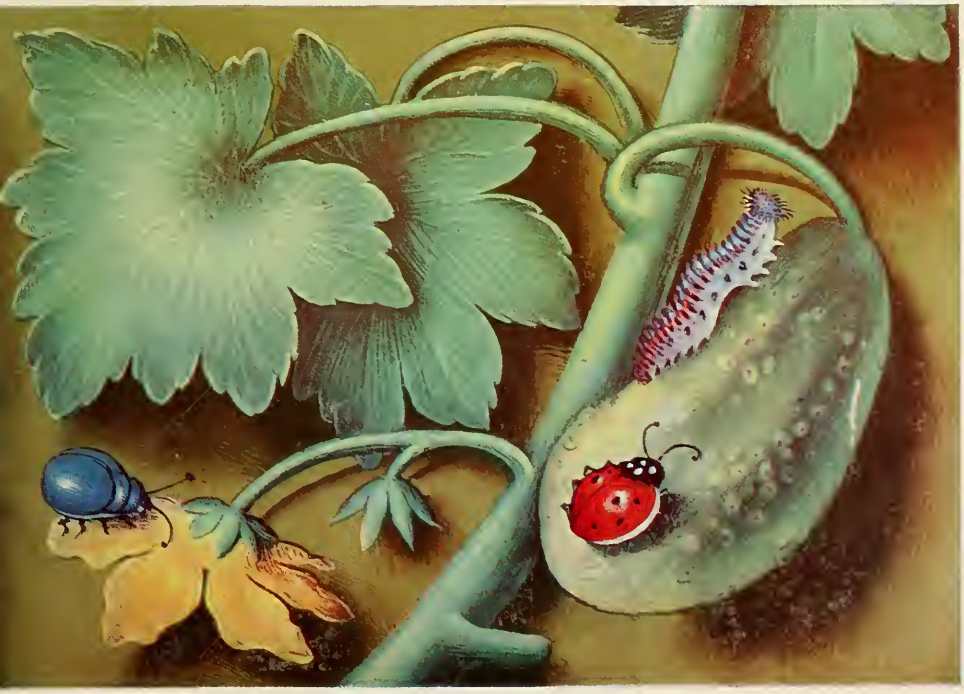


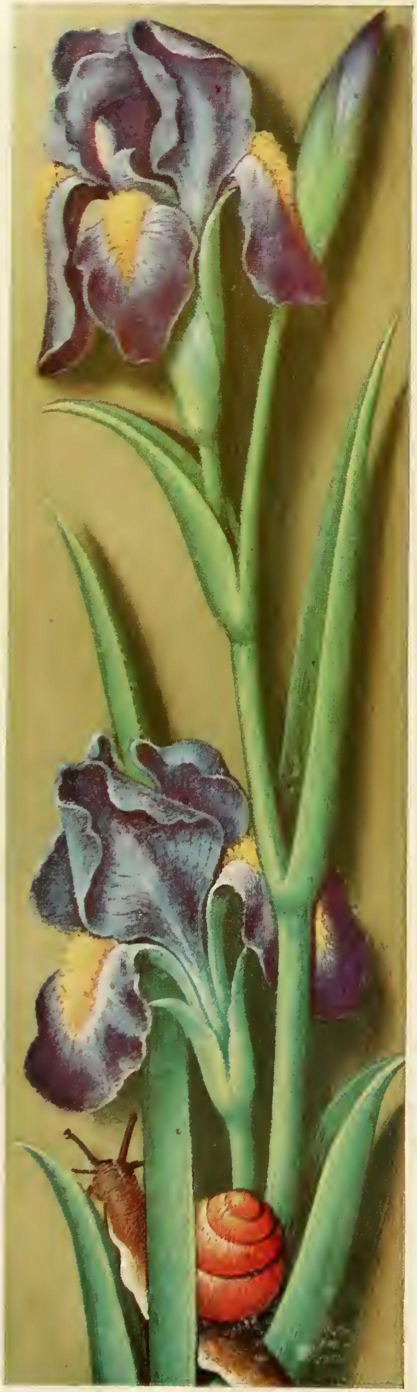


Cucumber "potage," said an herbalist, was good for the lungs and skin and was a cure for "red and firie noses (as red as red Roses) . . ."

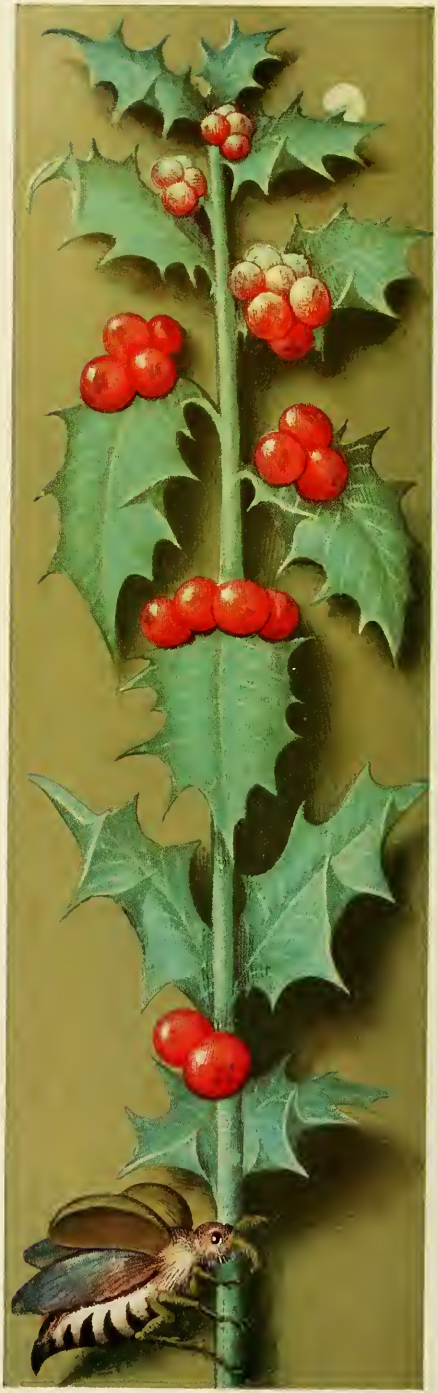


Enlarged detail of plum border in Book of Hours shows intricacies of miniaturist's art. Plum leaves and fruit were both used medicinally.





IRIS



holly

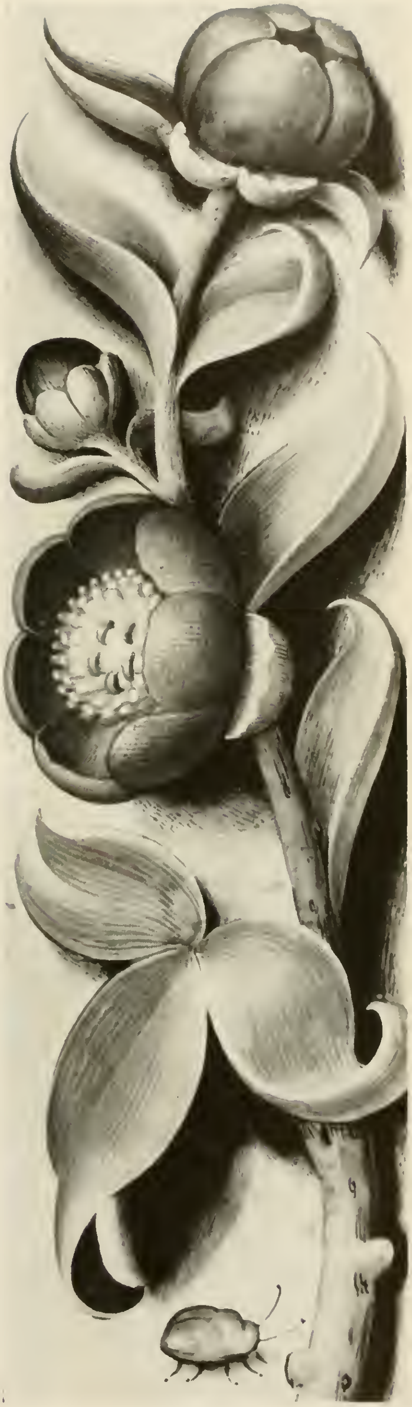
On these pages are Bourdichon's studies of the iris, the holly (both in color, *left*), and the peony, *right*, all plants that were included in herbals of the time. The purple petals of the iris, when mixed with alum, made a green dye much used by illuminators—perhaps by Bourdichon himself. Its powdered roots were recommended as a help for coughs and convulsions, for sore eyes, and for rough skin. Orrisroot, the scented rootstock of some European irises, is still used in cosmetics.

Holly berries were prescribed for colic, while the plant's bark was made into the sticky birdlime "which the birders and countrie men do use to take birdes with."

In some of the herbals that appeared during Bourdichon's time and shortly thereafter, astrological and mystical aspects of herb collection appeared. Much of the ridiculous—sometimes questioned, but often accepted—was recorded by the authors. Gerard, for instance, discussed the magical powers of the mandrake root and reported with great seriousness the remarkable barnacle plant from which sprang the barnacle goose.

The peony was part of this cult of botanical superstition. Herbalists dug it only after purification procedures and only by the light of the moon, for, says Gerard, ". . . if any man shall plucke of the fruit in the day time, being seene of the Woodpecker, he is in danger to lose his eies." The translator of Dioscorides added to the peony description in the old manuscript that it was "good against poisons and bewitchings and fears and devils and their assaults." Its association with the devil may account for the use of its seeds in mental illness and palsy, while "the fresh roote tied about the necks of children, is an effectuall remedie against the falling sicknesse. . . ." Childbirth would be eased if a woman took peony seeds, but she "must drynke fifteen seeds at one tyme."

Even the food grains (next pages), primarily classed among the "meates to maintaine life," were drafted into medical use—mainly as external applications. Wheat was deemed a cure for wounds, and white bread poultices then, as now, were applied to sties. Oats also made popular poultices—one for impetigo and one

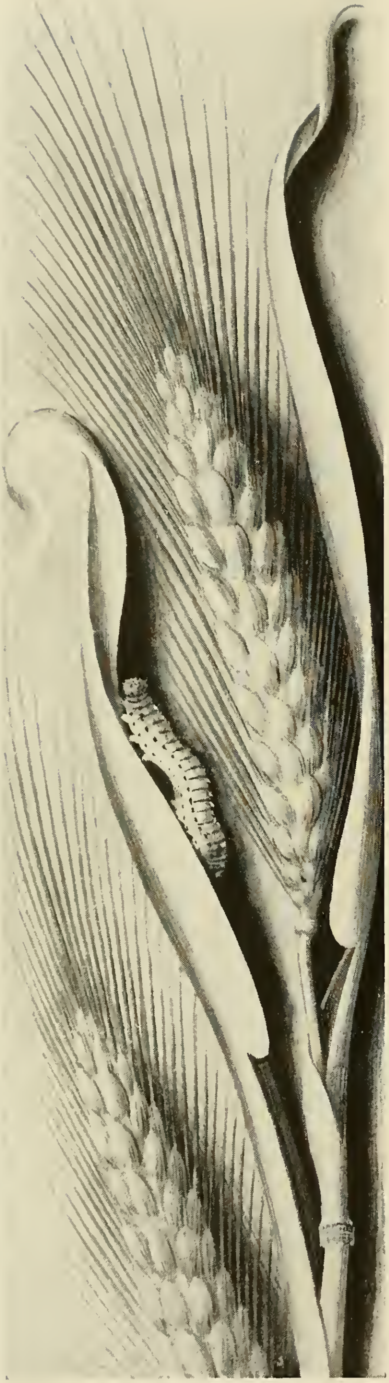


peony

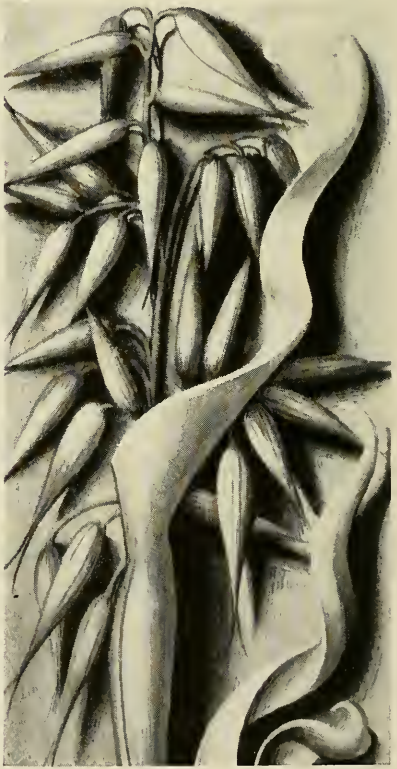
for a "stitch in the side." Gerard adds waspishly: "Otemeale is good for to make a faire and well coloured maide to looke like a cake of tallow, especially if she take next her stomacke a good draft of strong vineger after it." Rye was a specific for abscesses, while millet meal mixed with tar made a dressing for snake bite.

Despite the fact that plants had been used medically since antiquity, scientific observation lagged almost two millennia behind the speculative botany of Aristotle's day that concerned itself with such questions as whether plants had "souls." As printing and learning spread, however, this ancient, philosophical study gave way to medical botany and, thence, to the descriptive, or systematic, botany of the seventeenth and eighteenth centuries.

Early herbalists were medical men, and, as Agnes Arber, the British scholar, has pointed



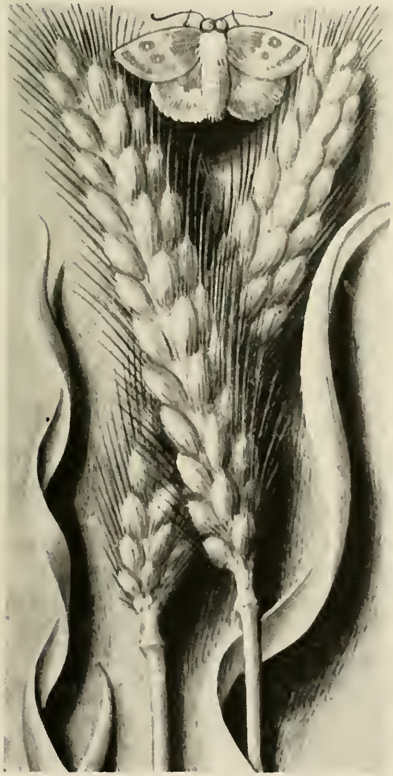
wheat



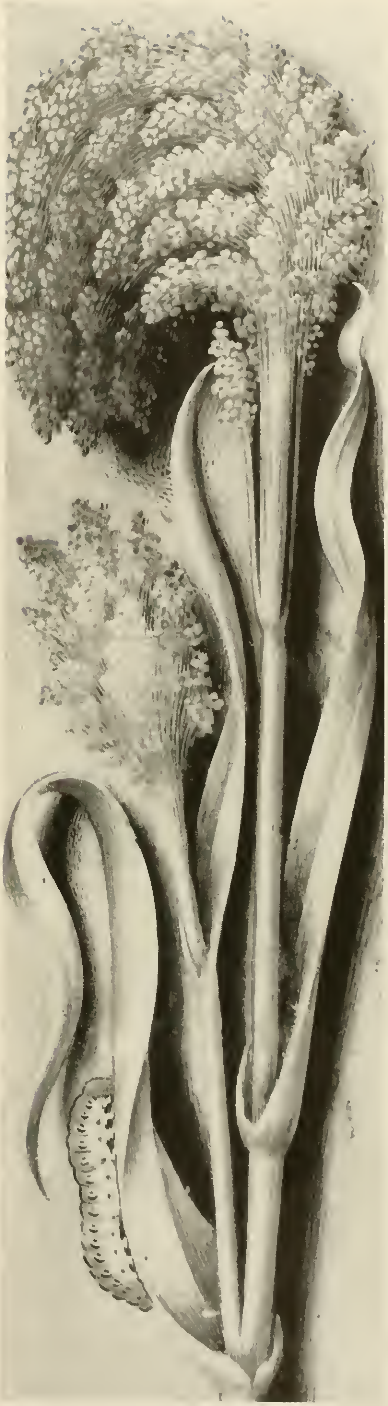
oats

out, possibly wrote their books to help readers find the particular plants used in medicine. However, both the descriptions and the pictures were so vague as to be almost meaningless. This fact has given rise to the suggestion that herbals were really only reference books for the already informed, because medical knowledge of plants was handed down primarily by word of mouth.

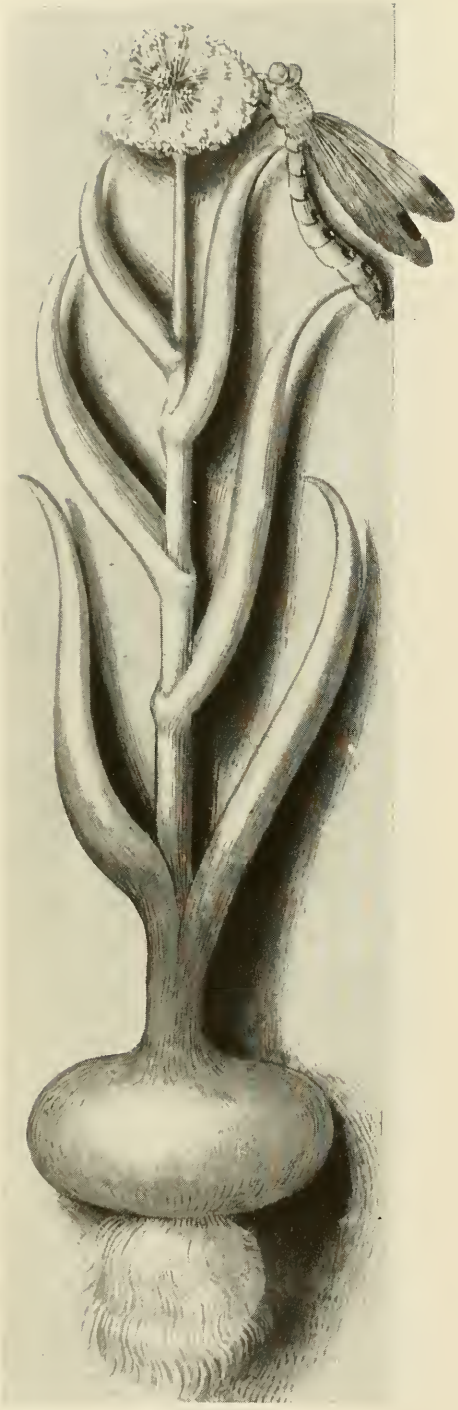
In this context, Bourdichon's accurately observed flowers are of particular interest. As a court painter, rubbing shoulders with the rich and learned, he may have been quite aware of the new, more exact science that was developing rapidly in his day. In a sense, his meticulous work foreshadowed it. In the same way, he foreshadowed a school of painting that culminated in the eighteenth- and nineteenth- century works of his countryman, Pierre Redouté, who also painted his flowers on vellum.



RYE



millet



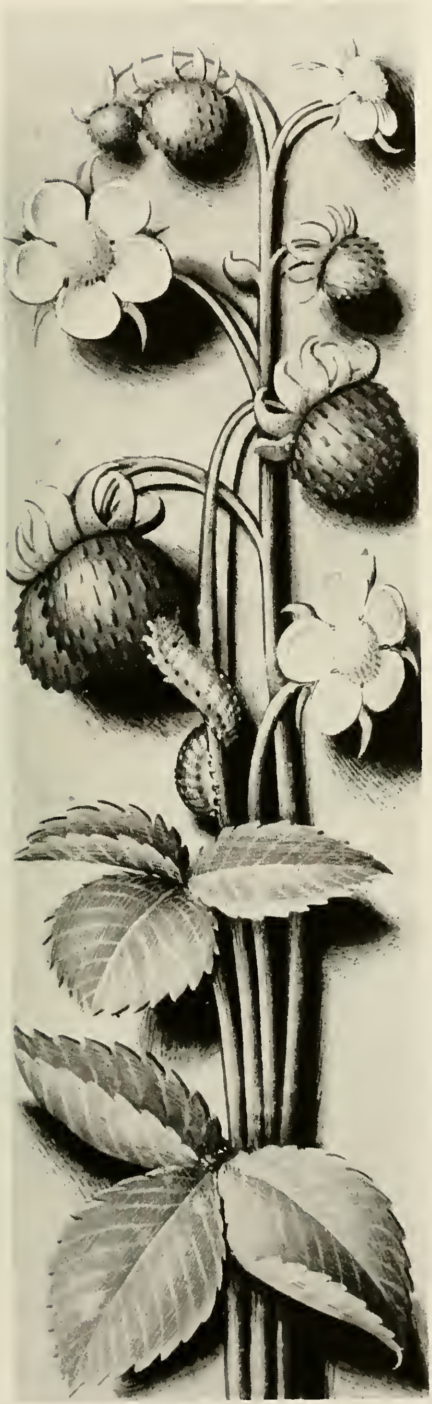
onion

During Bourdichon's lifetime, however, the onion he painted, *left,* was strictly utilitarian. Its juice was used for baldness and for burns and, mixed with pennyroyal and applied with a feather, supposedly eased the pain of gout. It also cleared stopped-up heads, when sniffed, but was seldom eaten, for "The Onion . . . yea, though it be boiled causeth headach, hurteth the eies, and maketh a man dim sighted, dulleth the sences . . . and provoketh overmuch sleepe, especially being eaten raw."

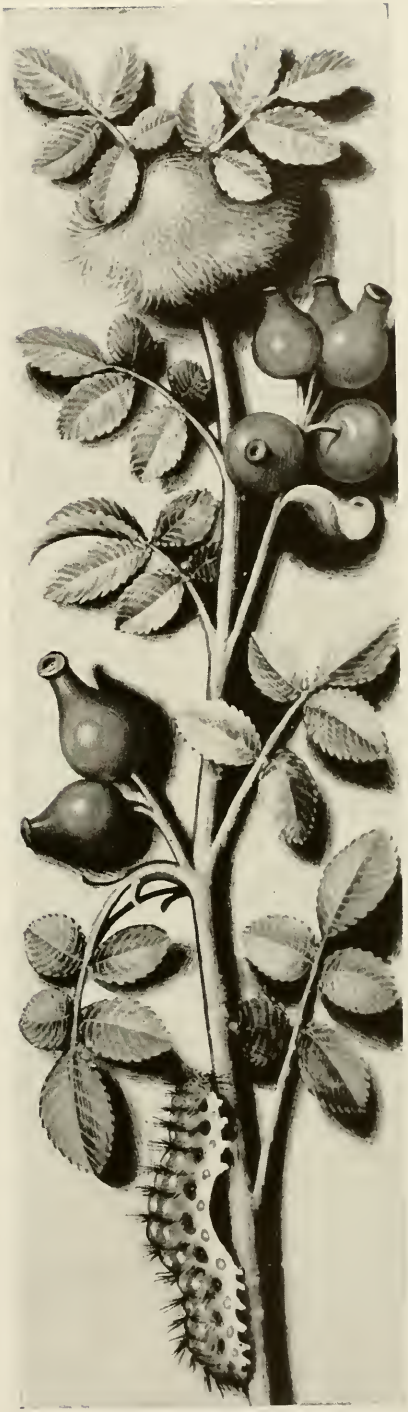
Strawberries, *right,* p. 590, probably had a double meaning for the artist. A part of Christian symbolism, the strawberry—which was not cultivated until the fourteenth century—represented perfect righteousness. Medieval paintings often showed the Virgin in a dress decorated with clusters of strawberries. In this case, they meant the good works of the righteous, or fruits of the spirit. They were also, to Renaissance doctors, a cure for a number of ailments. For instance, the leaves were taken with distilled water or wine for "passion of the hart," and "reviving the spirits," a process that the herbalists declared "maketh the hart merrie." Less romantically, leaves were used as poultices for burns and to "fastneth the teeth."

Today, the herbals of the Renaissance period are collectors' items among lovers of rare books, and are the joy of historical botanists. There has also come to be another use for them. Since the advent of curare, rauwolfia, and other new botanical drugs, pharmaceutical houses have begun to research many of the "old wives' tales" enshrined in the herbals. Now the research scientist, with laboratories at his command, is becoming—at least in part—a latter-day herbalist. His debt to the sixteenth-century collectors of botanical information is incalculable.

The debt owed to these early herbalists by today's plant lovers, too, can never be repaid. Pliny said of the wild rose, *far right,* that its roots were good for the bites of mad dogs. But, by 1597, John Gerard found in the plant an almost poetic pleasure: "The fruit when it is ripe maketh most pleasant meates and banketting dishes, as Tartes and such like: the making whereof I commit to the cunning Cooke, and the teeth to eat them in the rich mans mouth."



STRAWBERRIES



WILD ROSE HIPS

SCHOOLING FISH

What stimuli underlie this highly organized behavior?

By Evelyn Shaw

TO WATCH THE ACTIONS of great schools of fish in which the movements of the individual fishes are lost in the synchronous movements of the whole—like some huge, single animal—is to wonder about this pattern of behavior, so different from that of other socially organized, vertebrate groups. In a school, all the fish seem to behave alike and each school—whether mackerel, herring, tuna, or small shiners—resembles other schools in shape and form.

Of the many features schools have in common, the most surprising, perhaps, is the absence of a continual leader. A school may swerve to the right or to the left, fan out from the center, or change direction entirely. Each time, a different group of fish heads the school. As these movements of the school as a whole are made, there is also constant movement *within* the school—as each fish maintains its distance from the other fishes. The precision of orientation that is shown by fish as they swim in a school is rarely found anywhere else in the animal kingdom.

Schools may be composed of small, medium-sized, or large fish, but rarely are the sizes mixed—possibly because all the fish must travel in the same direction at the same rate of speed. The demands that such highly integrated behavior places on an individual fish are great. Each fish in the school must respond quickly and precisely to its fellow schoolers—and to environmental changes—in order to maintain the unified orientation of the whole.

Such elaborate response and counterresponse in schooling behavior presents many questions to the investigator. For example: What stimuli do the fish require to maintain their positional relationships? Do temperature, light, chemical substances, turbidity of the water, sunlight, clouds, and the like, influence the structure of the school and the direction the school will take? One experimenter, C. M. Breder, has shown that the small schooling fish *Jenkinsia* will recognize a temperature change of as little as one-half degree. Certain temperature gradients act as obstacles and *Jenkinsia* could not be forced to pass these temperature barriers. In contrast, other fish seem to be totally unaware of differences in the water temperature as they swim from one place to another.

Another important factor is the response of fish to light. These responses are highly variable when measured quantitatively, but most schooling fish are light-positive: that is, they are attracted to light. If there is very little light, as is the natural condition at night, schools tend to disperse —and do not form until light intensity increases with the coming of morning. Overcast days seem to affect schools by disrupting orientation. We have found that on clear, sunlit days the tightness and orientation of a school is enhanced. These observations present numerous possibilities of combinations of various factors for, without any doubt, schools of fish are influenced by their environment. But we want to know more about these influences and how they are mediated.

Blue acara fry, seen here with parent, were used for schooling-behavior tests in apparatus seen on opposite page.

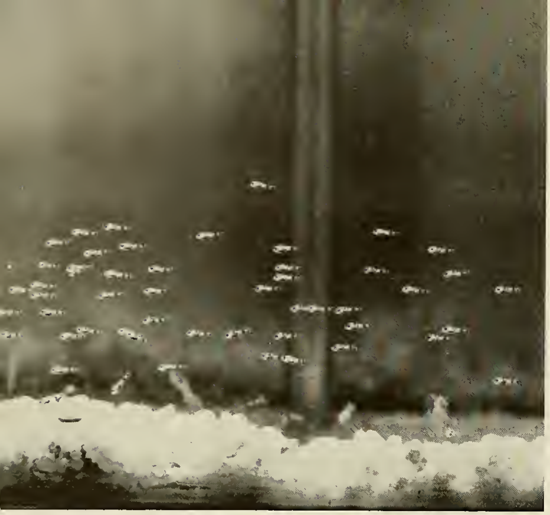
A school is made up of many individuals: it is possible that the observed responses in a school are simply a summation of individual reactions. If we may make this assumption, the schooling response can then be divided into two intimately related categories—the response of the entire school and the response of the individual.

The next question arises: How constant is individual behavior, and how strongly developed is the response to species mates? It seems highly unlikely that a fish "knows" that another fish is like itself. What it *does* "know" is that it has been surrounded, during growth, by fishes that have recognizable characteristics: it would thus tend to remain with those fish with which it has become most familiar.

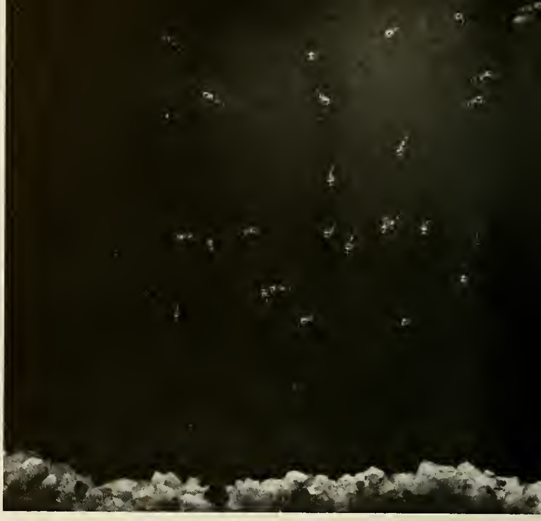
Since schooling fish tend to spawn in different places and at different times of the year, the chances of young fishes schooling with other than their own species are reduced. Even if they drift in the tides as plankton, they tend to be carried along together by the tidal action. Therefore, we generally find one species type in each school formation. We cannot justifiably say that fish of the same species seek one another, but we can assume that their coming together in schools is the logical result of a number of environmental conditions and circumstances.

To return to several questions posed earlier by this unique form of behavior: what are the stimuli that fish require to maintain their positional relationship in the school?

Vision, we know, is very important. Albert Parr, in 1927, postulated an approach to the means by which visual stimulus operates in allowing fish to maintain certain distances from each other. For example, if two are swimming side by side, they may be attracted to one another and steadily swim closer and closer. However, when they are too close, the attracting stimulus may become a repellent. Therefore, they swim side by side under the in-



Illumination affects the schooling of acara. Here, a group schools under combined incandescent and fluorescent light.



Dispersal takes place in a few seconds after fluorescent light is turned off. School is now completely broken up.

fluence of opposing, antagonistic stimuli—one tending to bring them closer together and the other tending to push them apart. An individual swimming between two companions, Parr postulates, will be visually stimulated, will perceive each companion, and will receive antagonistic stimuli on each side, resulting in the maintenance of certain distances from his companions. The distances observed in schooling formations may be a cumulative result of these antagonistic stimuli, occurring simultaneously in individuals throughout the school.

This is, of course, a hypothesis. As we observe the schools, we note that there is always variation in behavior. One cannot expect mathematical precision in actively swiming fishes. Although we do not yet know the "how" of visual stimuli, they have been clearly established as important. A number of investigators have eliminated visual stimuli by blinding fish, covering their eyes, and so forth. By thus preventing visual stimulus, they eliminated the schooling response.

One of the most fruitful approaches to problems in behavioral research has been to study the period in which the development of some element of behavior occurs — to learn when and how behavioral patterns appear. The analysis of schooling behavior in which we are now engaged has followed this approach. We began with observations on the first development of schooling. *Menidia*, the common silverside fish (also called whitebait, spearing, or shiner), has proved to be a satisfactory experimental animal for some of our studies. *Menidia* is small—the adults reach a maximum length of four to six inches. It lives in shallow water, where it is easily observed and easily collected by seining. The adults spawn from May to July, depositing their eggs on the soft, grassy, underwater banks of seashores. The eggs, which develop without parental care, hatch in about a week. The newly hatched larvae, five mm. long, drift with the tides, where they can be found randomly distributed among the plankton.

When the *Menidia* young have grown to twelve or fifteen mm. in length, they are no longer found with the plankton, but have formed into schooling groups, swimming in shallow waters. At some time during their growth from the larval, five mm. length to their greater size, the fry develop the specific behavior patterns they show in their schooling.

In order to study this crucial period of their life, it was necessary to rear young *Menidia* under laboratory conditions. After much trial and error, ways were found to do this successfully, thus permitting us to make observations on the development of the schooling response.

It had long been believed that schooling commences at the time of a fish's hatching. Our first, rather startling, observation was that schools did *not* form at that time. In fact, schooling did not begin until the fry had been swimming freely for three to four weeks, the time required to grow from their initial five mm. length to the twelve mm. size. Just after hatching, the fry showed no apparent response to their fellows. As they grew older and larger (some to seven mm. in length), they swam toward each other sporadically, but not in an oriented fashion. At nine to eleven mm. in length, they approached and occasionally lined up in twos, threes, or fours for several seconds, but they still did not achieve parallel orientation. However, when they had at last attained a length of about twelve mm., they began to school continuously.

These first schools were loosely structured: the fish did not maintain their parallel orientation consistently and did not always swim at equal speeds. But, by the time a length of sixteen mm. was attained, the fish formed tightly interwoven schools, maintaining parallel courses and a constant speed of swimming.

From these preliminary observations we learned two important facts. First, schooling in *Menidia* does *not*

Dr. Shaw, a research associate in the Department of Animal Behavior at The American Museum, has carried out her studies of fish at marine research stations in the Caribbean area.

Grouping begins again when light is restored, stressing the importance of adequate light in fish-to-fish response.

Reschooling is completed. Experiment will lead to tests of various aspects of light factors on schooling behavior.

appear immediately after hatching but develops gradually, following a characteristic pattern of approach and orientation. Second, fish-to-fish orientation, once schooling has begun, becomes increasingly precise as the fish grow more mature.

The latter fact suggested to us that schooling orientation may require some orientative experience. To test this possibility, four hundred fish were reared as individuals in physical and visual isolation. This was done by placing each embryo, before its eyes appeared, into an individual bowl. A coat of wax inside each bowl made it impossible for the embryo, as it developed, either to see out or to see its own reflection in the glass.

Of the four hundred fish raised in isolation, only four reached schooling age. When these four were placed with schooling fish of the same age, they joined the group. However, while these formerly isolated fish schooled, they were unable *initially* to maintain their positions in the school and frequently bumped into the other unisolated schooling fish.

Yet, after a few hours, we could no longer distinguish the isolated four from the other fish in the school by their behavior. Does this result mean that precision in schooling orientation is, to some extent, learned by experience? Such seems to be a reasonable conclusion even though this observation involved only four fish.

We now knew some facts about the development of schooling in *Menidia*. However, with this fish, we were restricted to study during the summer months. In searching for an experimental animal that could be studied in the laboratory all year round, we selected the cichlid fishes—for, in this species, the young school although the adults do not. One kind of cichlid in particular, the blue acara (*Aequidens latifrons*), is hardy and easy to raise. Their young school, in many instances, soon after they are freely swimming.

We reared acaras individually from the embryonic stage, in physical and visual isolation, until they were swimming freely. We placed these isolated acaras among schooling young of the same age. After fifteen or twenty minutes, they joined the schooling group.

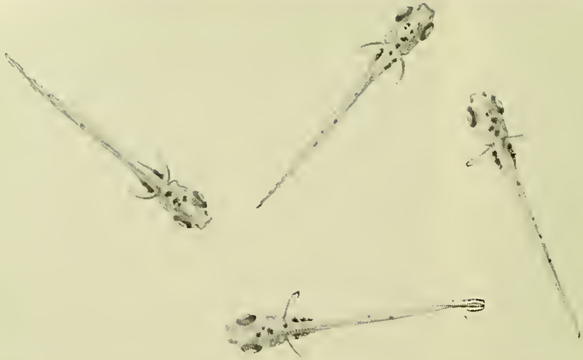
In another series of tests, these isolated fish — when placed only with one another — never formed into a school. At most, they joined in small groups after being together in the same tank for at least twenty-four hours. This test reinforced our observation that behavior is strongly influenced by the conditions under which the animals are reared and by the situation in which an animal is placed. The type of behavior elicited in a fish may very well depend on the behavior of its broodmates.

In a further effort to evaluate visual stimuli in the phenomenon of attraction, we carried out some experiments using both silversides and acara. The experiments were arranged as follows: a small, rectangular aquarium was separated into three vertical compartments by two glass plates. The center compartment contained the test fish. The compartments at either end remained empty until one (or more than one) fish was placed in one end or the other. Because the fishes were physically separated by the glass plates, the effect on our test fish of the presence of other fish was not influenced by any chemical, tactile, or vibratory stimuli.

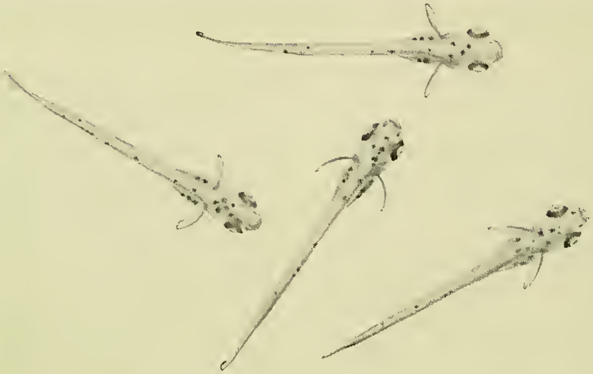
Neither silversides nor acara, in the test compartment, approached a *single* fish behind the glass plate in an end compartment. However, when two or more fish were put in the end compartment, young acara in the center would approach and orient.

This experiment has yet to be run with test silversides to see if they, too, will orient to a greater mass of fish. Since two freely swimming silversides will orient and school, however, it seems strange that the test silversides would not approach a single fish. It appears likely, from our preliminary study, that visual stimuli are not the *only* important ones in bringing two fish together and that other factors also operate in schooling.

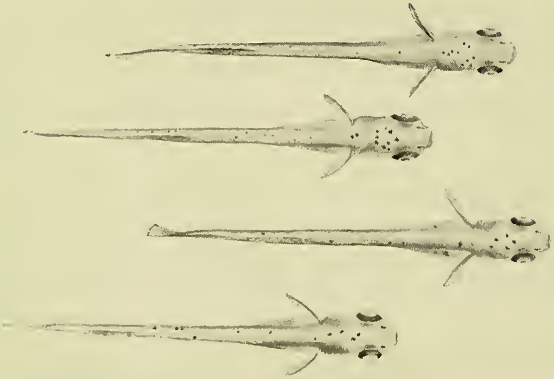
Light plays a very important role in the formation of schools. In one series of observations, it was found that light could influence both the



Early phases of schooling behavior of fishes shown here among *Menidia*, the silversides. Newly hatched, *above*, no fish shows any response to others.



Sporadic approaches to other fish in group begin as the *Menidia* fry grow larger. Occasionally, they line up in twos or threes for a few seconds only.



Precise schooling begins after the fish have been swimming freely more than four weeks. The *Menidia* fry, *above*, have now grown to sixteen mm. long.

formation and the breakup of a school. For example, when we turned on our overhead laboratory light at night, we would find silversides scattered throughout the aquarium. Within a few seconds, they became active and, within five minutes, they formed into well-integrated schools.

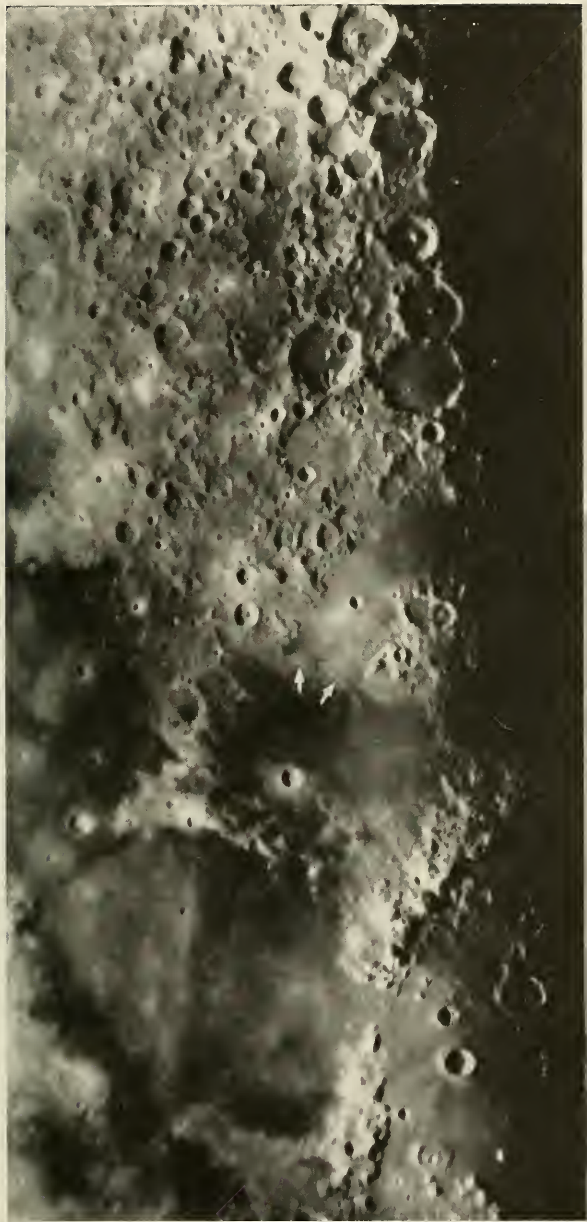
Different types of light also had different effects on the development of schooling in silversides. Those fish that were raised under cold, fluorescent lights schooled earlier than fish reared under incandescent lamps. Among the former group, moreover, the schooling orientation was more precise than among the latter.

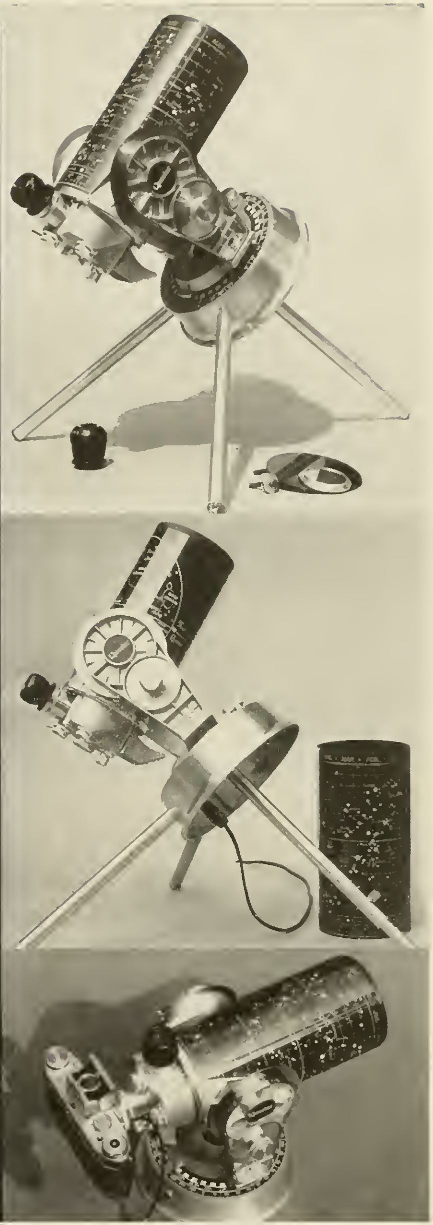
In another series of experiments, it was found that acara also respond directly to different conditions of illumination. This was demonstrated when acaras were placed in a special apparatus—a doughnut-shaped tank, with a channel three inches in width, filled with water and its bottom lined with gravel. Above the channel, at a distance of twelve inches, was a circular, 32-watt, cold fluorescent light (photograph, p. 592). The ceiling of the room housing this apparatus carried 300 watts of incandescent light. This ceiling light was kept on throughout the experiment, so that the channel was never in the dark.

When placed in the channel with the fluorescent light on, the acaras schooled immediately. When the fluorescent light was turned off, the school dispersed despite continued illumination from the ceiling light. By turning the fluorescent light on again, we could cause the school to re-form (photographs, pp. 594-95).

This has been a tantalizing observation. It will lead us into explorations of light intensity, wave length, polarization, and the like—and the effect of these factors on schooling behavior. What characteristic of the light is responsible for this remarkable effect? Does it alter the appearance of the fish in their response to other fish? These are only a few of the problems to be explored.

In this brief review of our recent experiments, we have presented only a few of the many questions facing the student of schooling among fish. We hope some day that our investigations—as well as the work of others—will help to answer some of the questions raised by this intriguing example of highly organized social behavior.





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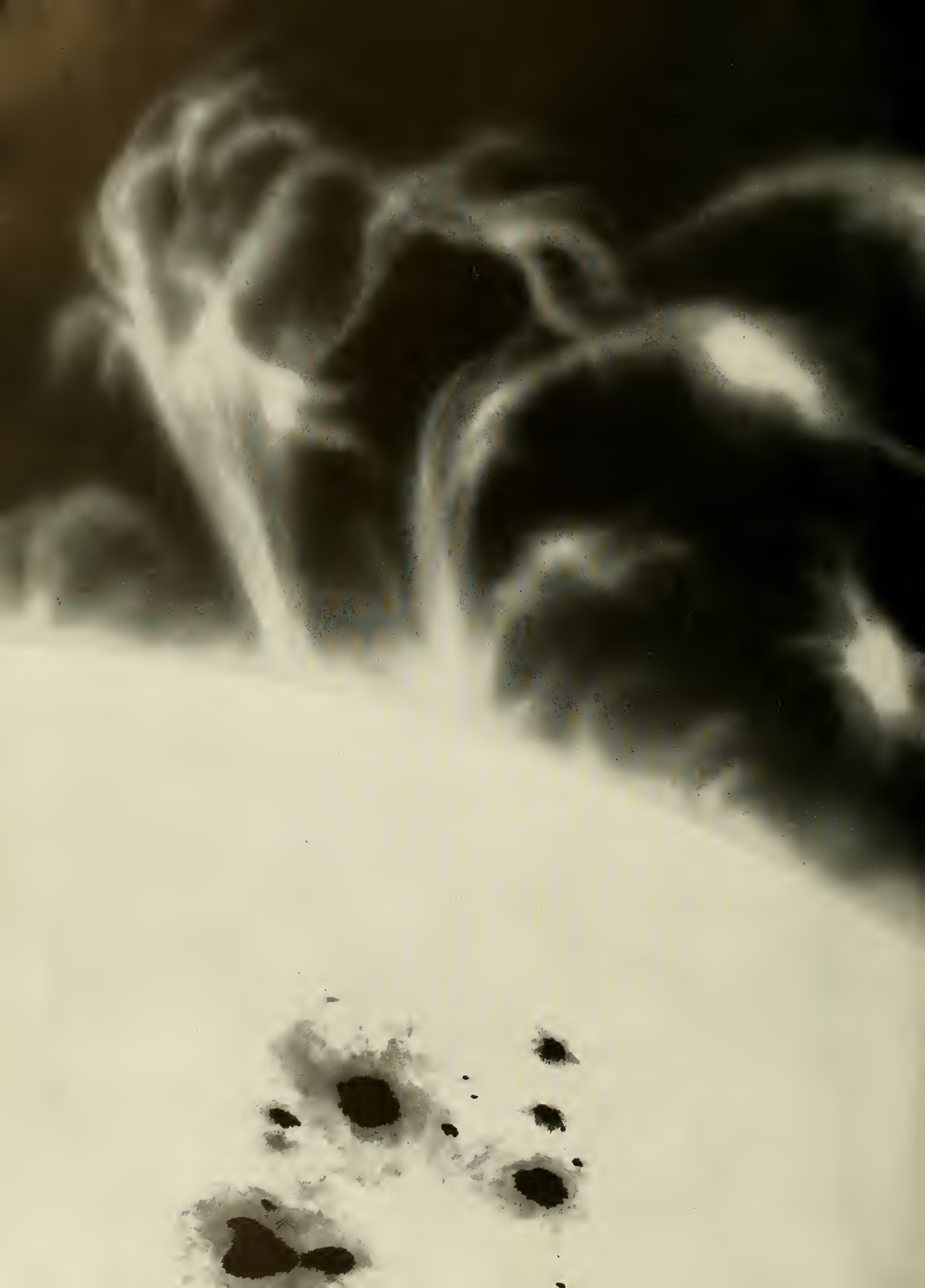


WHAT ABOUT WEATHER?

A new factor under study is the impact of radiation from the sun

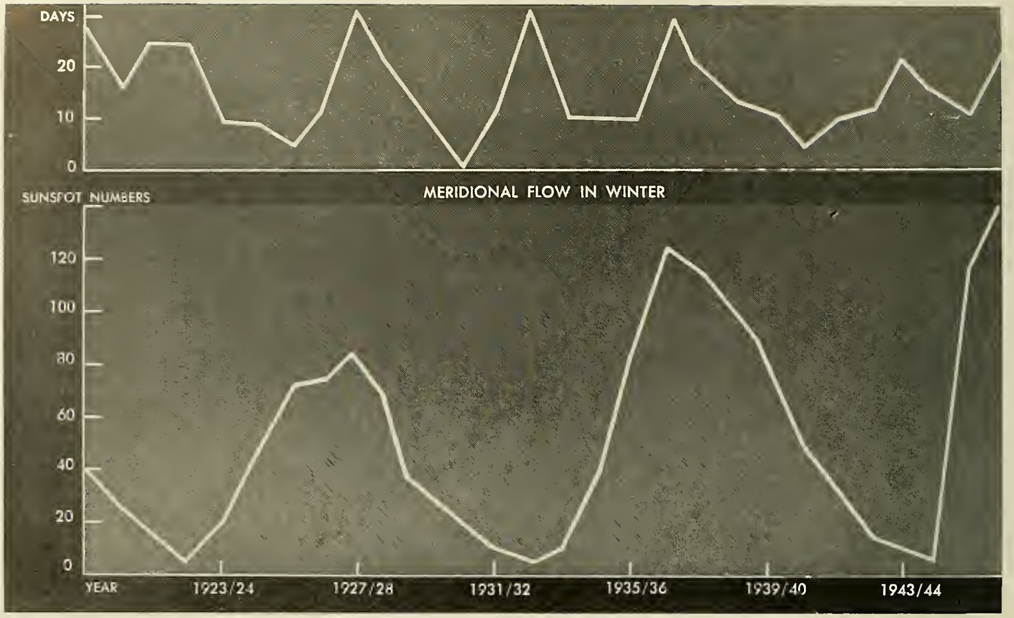
By Norman J. Macdonald

THE RELATION OF SUNSPOTS to the weather has been a controversial subject almost from the day that sunspots were first observed by modern methods in the seventeenth century. The subject is still much in debate today, but there are signs that the controversy may be about over. Observations during the International Geophysical Year and some new analytical tools for the study of world-wide upper atmospheric circulation have given us a new look at solar effects on the weather. In the future, accurate weather predictions more than a few days in advance may well depend on our ability to forecast the variations of solar activity associated with sunspots.

If the average midwesterner feels that winter heating bills have increased during the past few years, it is not just his imagination. January temperatures have shown a remarkable and complete reversal during the past decade or so. A cold West Coast and warm Atlantic seaboard, as they existed during the late 1940's, have been replaced during the last few winters by persistent cold weather east of the Rockies, while the continuation of mild winters west of the Continental Divide has contributed to an explosive growth of population. About two years ago, to cite another recent change, a dramatic break in the prevailing drought took place in the southwestern United States. Within a matter of weeks, floods replaced dust. Simultaneously, one of the worst dry spells on record got under way in the northeast and north central United States.

What causes these large changes from year to year and decade to decade? Some of us believe that variable solar activity may play a role. But solar influences, while they may be important, are certainly not the only forces at work on such patterns as these. Before exploring the sun-weather hypothesis, therefore, we must consider both the present status of long-range weather forecasting and the future prospects for improved accuracy in this field. To date, progress in the prediction of weather events beyond a few days has been slow. In fact, the exact prediction of *day-to-day* variations of weather at specific places for long periods is probably well beyond our grasp in the immediate future. But meteorologists are less skeptical about the prospects for an improvement in forecasts

Solar activity, *left*, includes flares in sun's atmosphere and spots on surface—seeming dark since they are 1200°K. cooler than adjacent area. Earth's nearness is imaginary.



Positive correlation between solar activity and events in earth's atmosphere is seen in graph, *above*. Peaks of winter air flow north and south along the meridians (top) correspond to sunspot maxima and minima, shown in bottom line.

of *average* conditions, over *wide* geographical areas, for time intervals of as much as a season in advance.

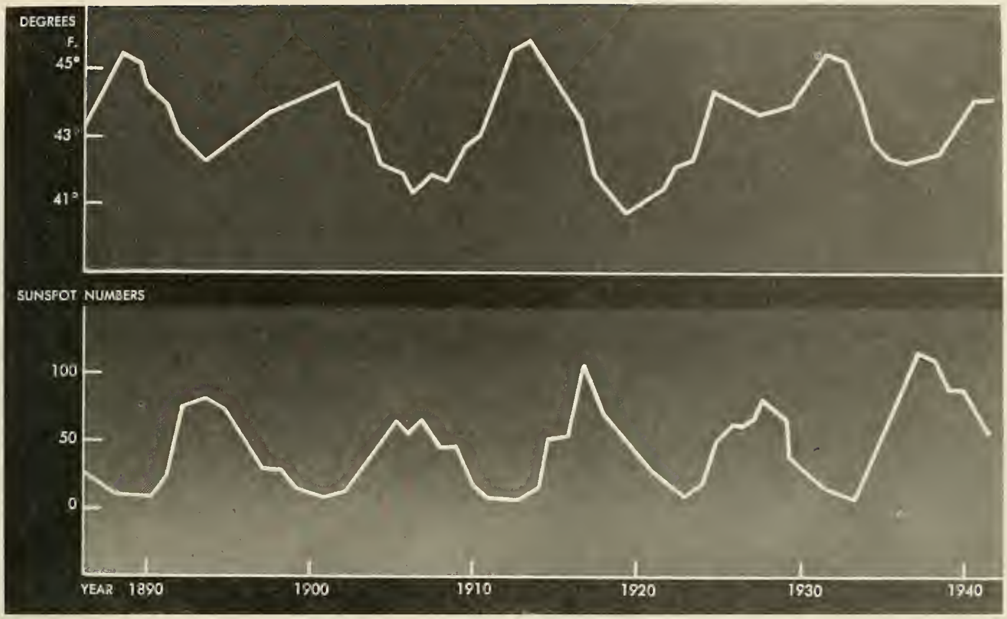
Changes in weather patterns are due to various restrictions that are imposed as the atmosphere, like most things in nature, continually tries to maintain an equilibrium. The rotation of the earth, the differences in heating produced by the changes of seasons, and the distribution of the earth's land and sea masses all introduce an imbalance of heat and energy over the entire globe. The atmosphere attempts to equalize temperature, for example, by bringing cold air south from the Pole and tropical warmth to the Arctic. In this process, a world-wide motion of the air is established — the "general," or large-scale, circulation of the atmosphere. But mountain barriers, large land masses, and great expanses of ocean lie along the usual route of this flowing air. This results in "natural" spots where the circulating atmosphere can brew storms or high-pressure areas, establish "jet streams," and develop all the other phenomena that make up our normal weather.

Over a *short* term, even day-to-day fluctuations in weather—connected with moving high- and low-pressure systems and their associated "fronts"—are sometimes significant. Seemingly innocuous low-pressure systems, with the inclement weather attendant upon them, will suddenly "explode" into gigantic storms that spread bad weather over nearly half of continental North America. Most meteorologists believe that such violent changes in surface weather systems are caused by, or associated with, subtle changes in wavelike disturbances located at much higher altitudes — in the part of the atmosphere where the jet stream is most often found. This meandering "river in the sky" is most often located eight to twelve kilometers high, in the boundary region between troposphere and stratosphere—where the greatest wind speeds in the low atmosphere are found. Accordingly, the trend of much recent research in meteorology has been directed toward understanding the birth, motion, waxing and waning of the upper atmospheric wave systems in or near the jet stream.

Sometimes, however, something happens that causes a shift in the atmosphere's general, *large-scale* circulation. Then, more dramatic weather abnormalities take over. Storms may brew in the central Pacific, instead of in their "normal" spot off the east coast of Asia. In summer, hurricanes may form in the Gulf of Mexico instead of in the Caribbean. In winter, masses of cold, arctic air will plunge suddenly southward into Texas and Florida, leaving the citrus crop in ruins, while Alaska basks in unaccustomed nighttime warmth. These disrupting, north-to-south (or south-to-north) motions of the atmosphere along the meridians — called meridional flow by meteorologists — cause most of the extreme fluctuations of weather that we experience over the long term.

To explain weather changes that last from a few days to a year or so—and even for intervals as long as a generation — some students hold that the atmosphere is essentially closed to any external influences. The changes we observe in weather and climate, in their view, result from periodic, *internal* oscillations in the atmospheric system. Such fluctuations of pressure, temperature, and other elements, they postulate, are the result of complicated mechanisms operating through changes in ocean currents, or the amount of ice or snow pack in the Arctic, and other, perhaps more subtle, causes.

Recent research does indeed suggest that these mechanisms, and the quasi-periodic exchange of air masses



Negative correlation can be equally significant, as in chart showing April temperatures in Bismarck, N. D. (top), and sunspot numbers (bottom). Lower sunspot activity parallels higher temperature, as storm tracks pass to north of region.

between the Northern and Southern Hemispheres, may be important weather factors. But most of the evidence shows that changes in the planetary, large-scale atmospheric wind systems actually *precede* changes of ice packs or ocean currents. Thus, while the geophysical variables inside our atmosphere may be secondary, modifying factors, they are probably not the basic cause of large-scale weather changes.

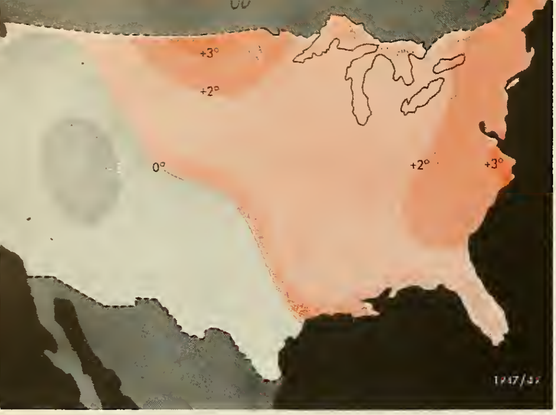
A few years ago, the "greenhouse hypothesis" was advanced to explain one such large-scale change—the warming trend observed over the Northern Hemisphere during the past half-century. This theory holds that, by increasing the carbon dioxide in the atmosphere through combustion, man may inadvertently be raising world-wide temperatures. The amount of carbon dioxide in the air at the present time is approximately 0.033 per cent by volume. If this amount were to be doubled, the atmosphere's absorption of heat as the earth radiates it back into space would be increased, and world temperatures would rise by about 3.6° F. On the other hand, if the present amount of carbon dioxide were halved, the temperature would drop by nearly 3.8° F. There is some indication that increased industrialization has changed the amount of carbon dioxide in our atmosphere from an estimated 0.025 per cent in 1900 to its present-day value of 0.033 per cent.

Indeed, this increase might explain the rise in Northern Hemispheric temperatures of about 1° F. That has been observed over the past half-century, were it not for the balancing effect exerted by the oceans. The surface of the ocean is usually quite effective in absorbing carbon dioxide, and these surface layers are constantly mixing with the water from lower depths. This probably causes the world's seas to act as a regulator, maintaining a nearly constant amount of carbon dioxide in the atmosphere of our planet.

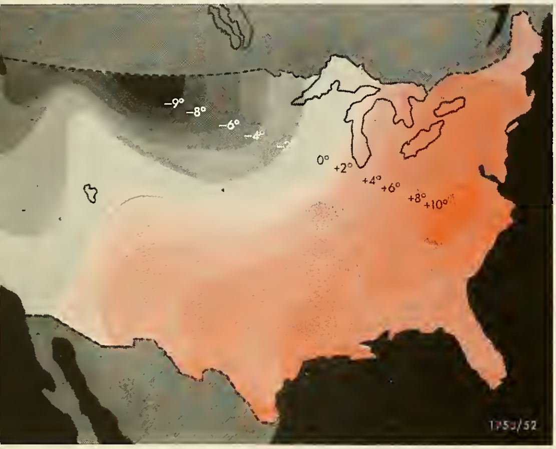
Other arguments have been advanced to explain long-term weather changes, including possible effects of volcanoes, H-bombs, and so forth. But these hypotheses cannot withstand the counterargument that such effects would be only temporary and, by their very nature, intermittent—hardly capable of causing the large and persistent changes that have been observed during the past few years.

One of the oldest hypotheses to explain both long-term and short-term weather changes is that a direct relationship exists between the earth's weather and the observed variations in sunspots. But it was only a century ago that the cycle of change in sunspots—from maximum number of spots to minimum number and back again, all in about eleven years—became known. This was soon followed by the discovery of a corresponding cycle of change in the disturbance of the earth's magnetic field; and still another, similar cycle was found in the activity of the aurora (or northern lights), whose association with terrestrial magnetic disturbances had already been noted by a half-century before.

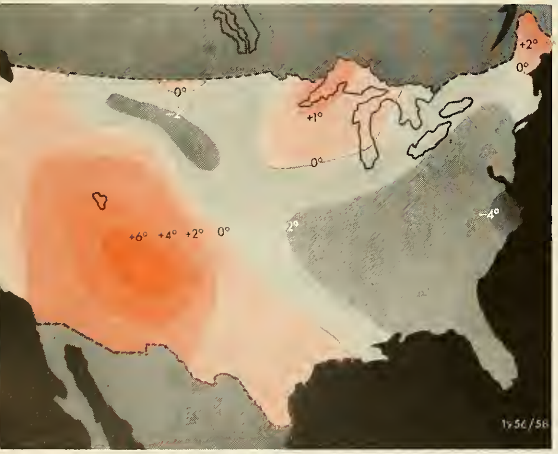
Although sunspots, as we now know, are only *symptoms* of the real nature of the sun's variable radiation, most statistical studies during the early days of research on solar influences affecting the weather, attempted to correlate the size and/or number of sunspots with variations of surface weather elements. Sir Gilbert Walker, one of the first to use this approach, compared annual average sunspot activity with annual averages of temperature, pressure, and rainfall in many parts of the world. He did not find any consistent correlation of sunspots with pressure or rainfall, but it was a different story with temperature. Walker found that, in the tropics, temperatures were low when



Changing U.S. temperature pattern for January is seen in three maps, in which figures indicate departure from mean.



Reversal begins as cold air masses, previously in the west, move northeast, as warmer, eastern masses swing to south.



Completed reversal, with warm winter weather now in west while east is cold, is only one of recent weather anomalies.

sunspot activity was high. He attributed this fact to a significant difference in the total amount of solar radiation, brought about by the change in the number of sunspots. Although Walker's results are statistically significant and are strong indications of some real sun-weather relationships, the coefficients of correlation are too small to be used for any practical purpose in forecasting.

Some of Walker's results were confirmed indirectly by R. Hanzlik, in Austria, a few years later. In fact, we should classify Hanzlik's work as among the most successful of these earlier efforts to establish sunspot and weather connections. Hanzlik analyzed barometric pressures at a worldwide network of stations for the period from 1842 to 1920. For each station, he compared the mean pressure for the three years centered at sunspot maximum with the mean pressure for the three years centered at sunspot minimum. From the subtropics to the Equator in both hemispheres, Hanzlik found that pressure *decreased* from the time of sunspot minimum to the time of maximum. Now, in the tropics, lower pressures are generally associated with increased rain, cloud cover and, consequently, lower temperatures—an indirect confirmation of Walker's earlier results.

More recently, a most controversial sun-weather hypothesis had been championed by C. G. Abbott, research associate at the Smithsonian Institution. Abbott postulates that changes of weather elements at specific points over large areas are caused by variations in the so-called solar constant—the total amount of solar energy reaching the earth. Abbott claims that the solar constant, in turn, is significantly changed by sunspots and solar activity. Further, he purports to show various periodicities in weather elements, which are related to similar periodicities in the solar constant. With some modifications, Abbott has used this basic technique to make weather predictions for many locations years into the future. Although he still claims that his method is quite accurate, independent verifications have yet to confirm its reliability.

The lack of this hard test of reliability is not the only point of disagreement with Abbott's theory. For years, it was assumed that the value of the solar constant varied by as much as five per cent with changes in sunspot activity. During the last generation, however, it has been shown quite conclusively that the amount of solar energy reaching the earth does *not* change to any extent through the sunspot cycle. Indeed, the part of the sun's radiation that *does* vary is absorbed high above the earth's surface, in the tenuous, outer atmosphere. In consequence, the variation in the solar constant is very small—probably less than 0.3 per cent. Thus, Abbott's work—and other early studies that emphasized a direct relation between the solar constant and weather changes—fell into discredit when it became clear that there were no *large* changes in the amount of total radiation received from the sun.

Nevertheless, statistical evidence has continued to accumulate in support of a sunspot-weather relationship. In the 1940's, some rather convincing evidence of connections between long-term variations of drought conditions and sunspot numbers was shown by I. R. Tannehill. He analyzed time variations of selected weather elements at many stations for the period extending from the late nineteenth century to the 1940's. Most of these variations show a striking parallel with sunspot numbers over the

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same period. From these stastistics, the implication is clear that droughts in the southwestern United States are likely to occur during alternate periods of sunspot minimum. While no coherent theory emerges from his study, Tannehill's data are impressive as further evidence for connections between solar activity and the weather.

By the mid-1940's, then, if we had summarized all these statistical analyses, we could probably have concluded only: (1) that droughts in the southwestern United States occur at about twenty to twenty-two year intervals, during alternate periods of low sunspot activity; and (2) that lower temperatures and lower pressures occur in the tropics during periods of high sunspot activity. Indeed, one may say of these early studies that, despite the wealth of statistics they furnished, they failed to reveal broad patterns valid and consistent enough to be used in actual forecasting. To find these patterns, meteorologists turned from the study of specific weather elements to that of the large-scale circulation of the atmosphere.

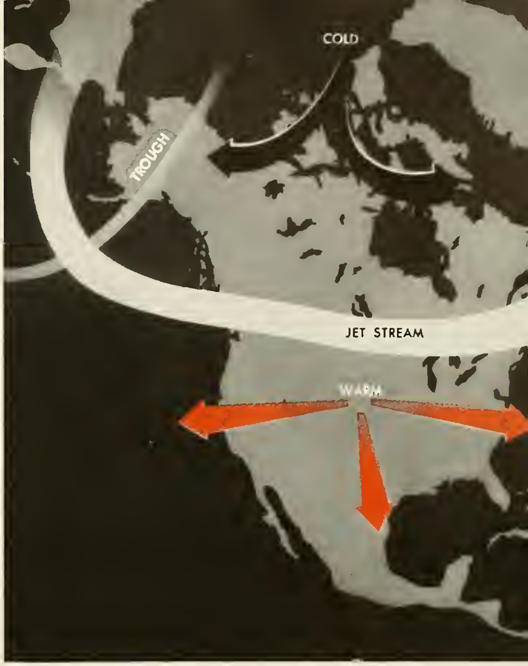
In the past ten years or so, H. C. Willett has championed one such approach to the practical understanding of sun-weather connections, employing the so-called "double analogue" system to describe broad features of atmospheric circulation. This method consists of selecting, from past weather maps, a number that are analogous over a large area to the current weather pattern and its evolution. From this set he selects one or two cases that occurred during periods of similar solar activity. Using these "analogies" as guides, he then develops a forecast, which may be prepared for a month or more in advance.

Although Willett has enjoyed some measure of success, most meteorologists doubt that this method can lead to any consistently useful long-range weather predictions. Part of the difficulty, Willett suggests, may be that he has been forced to use sunspot numbers in selecting the solar analogue to terrestrial weather—like many others. Willett would prefer a more direct measure of solar activity. Unfortunately, quantitative and reliable indices of the sun's complex changes, available to a limited extent since the mid-1940's, are practically non-existent before then.

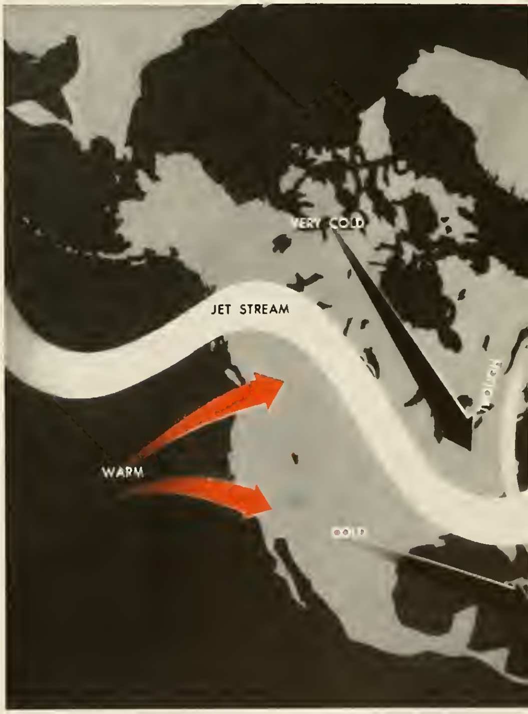
In Germany, F. Baur has taken the European lead in the modern approach to long-range weather forecasting. Like Willett, Baur assumes that solar activity affects the atmosphere's circulation over a large area. But, unlike Willett with his analogues, Baur attempts to interpret these large-scale features by describing the time and space variation of semipermanent high- and low-pressure areas. Changes of the intensity and position of these "centers of action," he shows, are often directly related to the establishment of departures from the average temperature or precipitation over broad areas. He then shows the relation of these changes to sunspot activity.

Baur concludes that there is a double oscillation within each sunspot cycle, which shows a tendency for similar features of the atmospheric circulation to recur at both sunspot maxima and minima—at least in the European area. Like Willett, Baur leaves the interpretation of the physical mechanisms that might explain this double oscillation as a problem for the theoreticians.

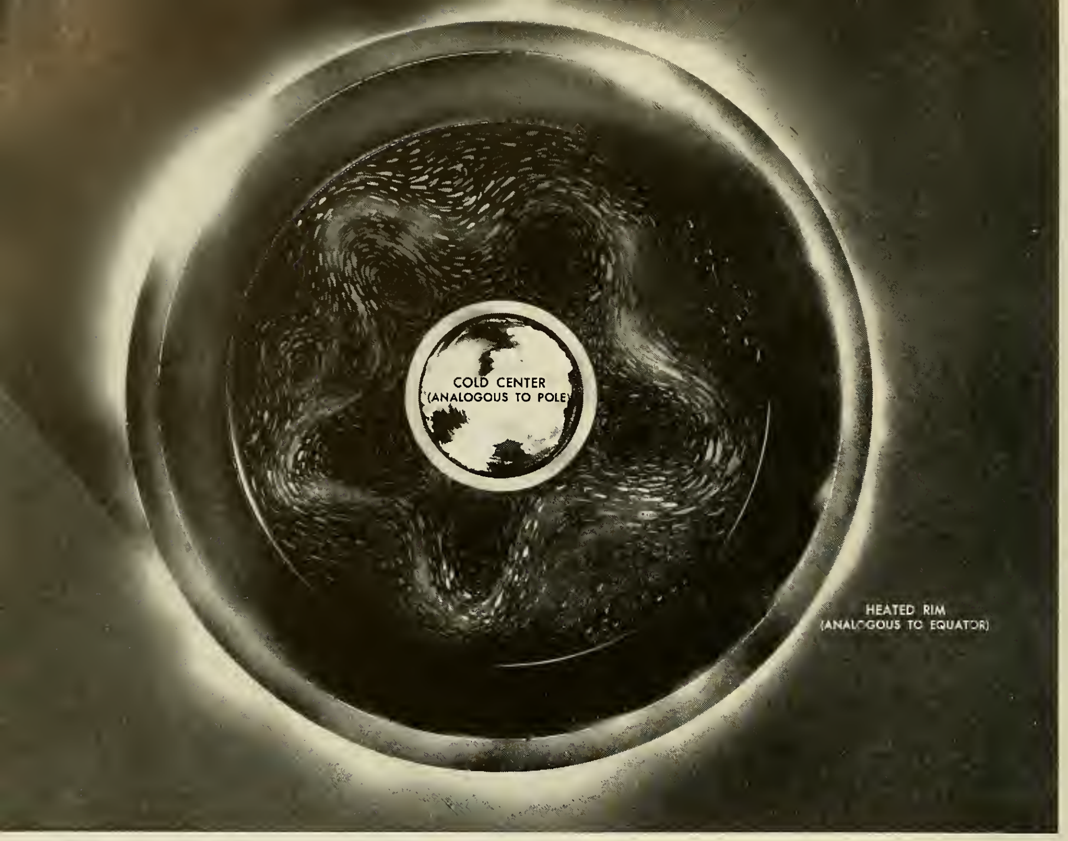
R. D. Elliott, the leading U. S. exponent of the "weather-type" system (very similar to Baur's) for weather forecasting, shows a similar type of correlation between weather patterns and sunspot maxima and minima. The effect can



NORMAL FLOW of jet stream is shown on day when trough, or wave disturbance, first appears as result of solar radiation.



MERIDIONAL FLOW—triggered by radiation—is erratic, wavy motion that transfers warm air north and arctic air south.



Dishpan experiment simulates main pattern of atmosphere's circulation. Rotating pan, with heat source at rim and heat sink in center, is partly filled with water. Fine aluminum particles prove water's motion is analogous to jet stream.

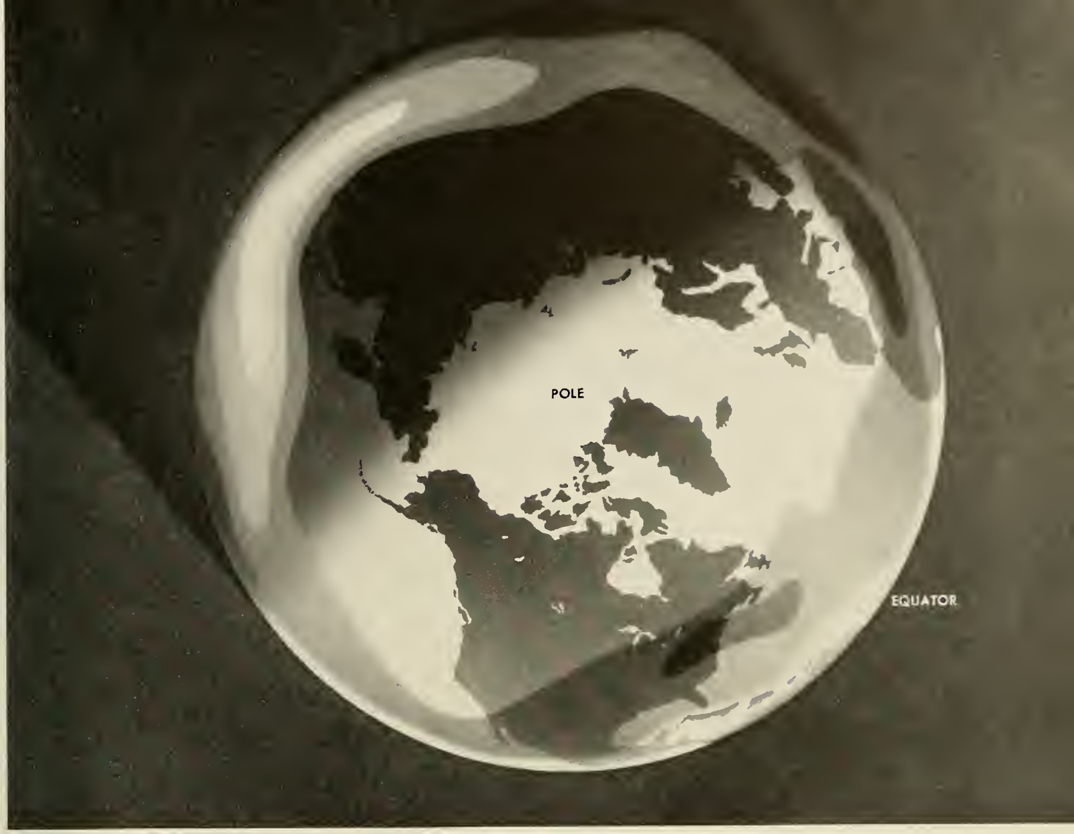
be shown by examining the graph on page 600. The top curve in the graph shows the occurrence of the north-south (meridional) patterns of atmospheric circulation for the winter season (December, January, February) of each year. If this is compared to the curve of annual relative sunspot numbers for the same period, shown as the bottom curve, the correspondence between the peaks of the meridional flow pattern (heat exchange along the meridians) and the sunspot maxima and minima is quite striking.

By the early 1950's, then, evidence had continued to mount in support of a sun-weather hypothesis. Furthermore, results were suggesting that the sun's effect was probably on the large-scale circulation of the atmosphere—which, in turn, produced changes in the more local weather elements as established by the earlier investigators. For example, unusual temperature or rainfall, like that studied in earlier work, is often caused by the transport and interaction of air masses as they move along the meridians from their opposing sources in the Arctic and Tropics.

In the past few years, particularly since the start of the IGY, some sun-weather and upper atmospheric investigations have produced intriguing results. This progress is partly the result of a new and co-ordinated attack on the problem by practical meteorologists and more theoretically minded astronomers. Scientists from both fields have benefited by this sharing of knowledge. The meteorologists, for their part, found that they had been working in the dark regarding the progress that solar physicists had made in understanding the real nature of solar activity.

As has already been mentioned, sunspots are not the only, nor even the basic, source of the sun's variable radiation: rather, they are symptoms of it. Among the phenomena associated with sunspots, for example, are regions of brightness on the sun's surface, somewhat warmer than that portion of the solar atmosphere surrounding them. Sunspots, themselves, appear dark because they are about 1200° K. cooler than the sun's surface temperature. Above this lower part of the solar atmosphere, but in the general vicinity of sunspots, lie other, bright regions called plages: in these plages, areas suddenly brighten into the solar flares that produce sudden increases in ultraviolet radiation (*see* Natural History; November, 1958).

We also know that, in addition to this ultraviolet radiation, the sun emits streams of particles—or, as they are also described, corpuscular clouds—at very high speeds. Most of these corpuscles are trapped in the sun's own atmosphere, but a surge of particles occasionally will find its way through the entire solar atmosphere out into space. Such a surge may reach the earth's atmosphere a day or



Jet stream is drawn in its average position for January, for comparison with dishpan's pattern. Values show geostrophic wind speeds: innermost contours represent areas of greatest speed (120 mph); outermost, those of slow speed (70 mph).

two later. These clouds of particles are absorbed very high in the earth's atmosphere, at a level of about seventy to a hundred kilometers: it is they that produce the aurora and disturb the earth's magnetic field.

As astronomers have stressed, then, the abundance of such phenomena and the amount of energy they involve makes the mere number of sunspots only one index—and a rather crude one—of the sun's activity. But the sunspot count *is* well correlated, positively, both with the sun's ultraviolet radiation and, in years near sunspot maxima, with the emission of solar particles as well. As for disturbances in the earth's magnetic field and auroras, these probably indicate the strength of that part of the sun's corpuscular radiation that actually reaches the earth.

Some of the results of this co-ordinated new look at solar effects have come to light only in the last year or so. Most of them are indicative of pronounced solar influences. In Japan, Y. Arai has shown that changes in the amplitude of the large, wavelike disturbances we sometimes find in the atmosphere are strongly associated with changing solar activity. At times of low solar activity, much of the atmosphere's energy is concentrated in one wave, most often located off the coast of Asia. But as solar activity increases and sunspots, flares, and abrupt magnetic disturbances become more frequent, the energy is distributed more equally into other wave systems throughout the Northern Hemisphere. Now, N. La Seur had previously found that dry weather tends to occur in the southwestern United States at times when the atmospheric energy (as measured by wave amplitude) is concentrated into one long wave system. So here is a possible physical explanation of Tannehill's statistics, which show an association of southwestern drought with alternate sunspot minima.

The Russians have been active, too. V. F. Christyakov has shown that lunar haloes are caused by the scattering of light from the high clouds preceding low-pressure systems (storm centers), so that the distribution of such haloes provides a clue to changes in the general circulation of the atmosphere. Christyakov notes a pronounced shift in the latitudes of maximum halo frequency—a shift that is closely correlated with solar activity. The correlation leads Christyakov to conclude that, at times of high solar activity, there is an intensification of storm centers, a southward shift of storm tracks, and a greater transport of air along the meridians. This meridional shift, he infers, should result in warmer temperatures in northern latitudes and lower temperatures in the tropics. Thus the mechanics are provided for the "cool tropics" found at the sunspot maxima by Hanzlik and Walker.

Mr. Macdonald is an alumnus of the California Institute of Technology, where he specialized initially in physics and then, as a graduate student, in meteorology. He is at the High Altitude Observatory in Boulder, Colorado, again combining physics and meteorology in his weather studies.

Among the Americans, R. Shapiro has recently found evidence of a solar effect on atmospheric circulation in the European area. In earlier studies of the circulation of the atmosphere over North America, Shapiro had noted an increase in the persistence of weather patterns from four to eight days after a magnetic disturbance, followed in turn by an abrupt change to low persistence of patterns about fourteen days later. In the newer, European study, Shapiro failed to find the same break in persistence fourteen days after the magnetic disturbance. But the *increase* was again found to occur, and with the same time lag as in the first study. The results of this work strongly suggest that the atmosphere first shows a response to the arrival of solar particles with about a four-day to an eight-day lag.

At the High Altitude Observatory, we have analyzed the evolution and development of wave disturbances at the jet stream level of the atmosphere during the recent period of maximum solar activity (1956-1959). We found that in the Gulf of Alaska, two to four days after the arrival of a corpuscular cloud from the sun, the meridional components of the waves were likely to increase, developing into a large disturbance like that shown on page 603. The meridional component of motion reached a maximum, on the average, when the disturbance reached its maximum size.

But efforts to study sun-weather connections by using mathematical models to describe the circulation of the atmosphere have not yet been able to show any evidence that solar influence on the *lower* atmosphere is important. Work done by Y. Ooyami and J. Spar — and some preliminary efforts by the Russians — have shown that even with intense heating from the sun at heights of seventy to one hundred kilometers, there is very little solar effect at lower levels of the atmosphere. The rapid increase of atmospheric density strongly damps the downward propagation of these disturbances to lower elevations.

There are, of course, many other problems still to be solved. Where should we be looking for mechanisms that might link solar and terrestrial phenomena, and for more definitive explanations of the solar effects? The answers may lie outside the scope of present sun-weather research. Perhaps they will come, for example, through further investigation of E. G. Bowen's hypothesis that meteor dust may have important effects on rainfall. Support for this hypothesis, at one time a controversial one, has grown rapidly in recent years. K. Bigg, for example, has found that cirrus clouds in Australia frequently coincide with heavy rainfall that, as Bowen has observed tends to occur about thirty days after a meteor shower.

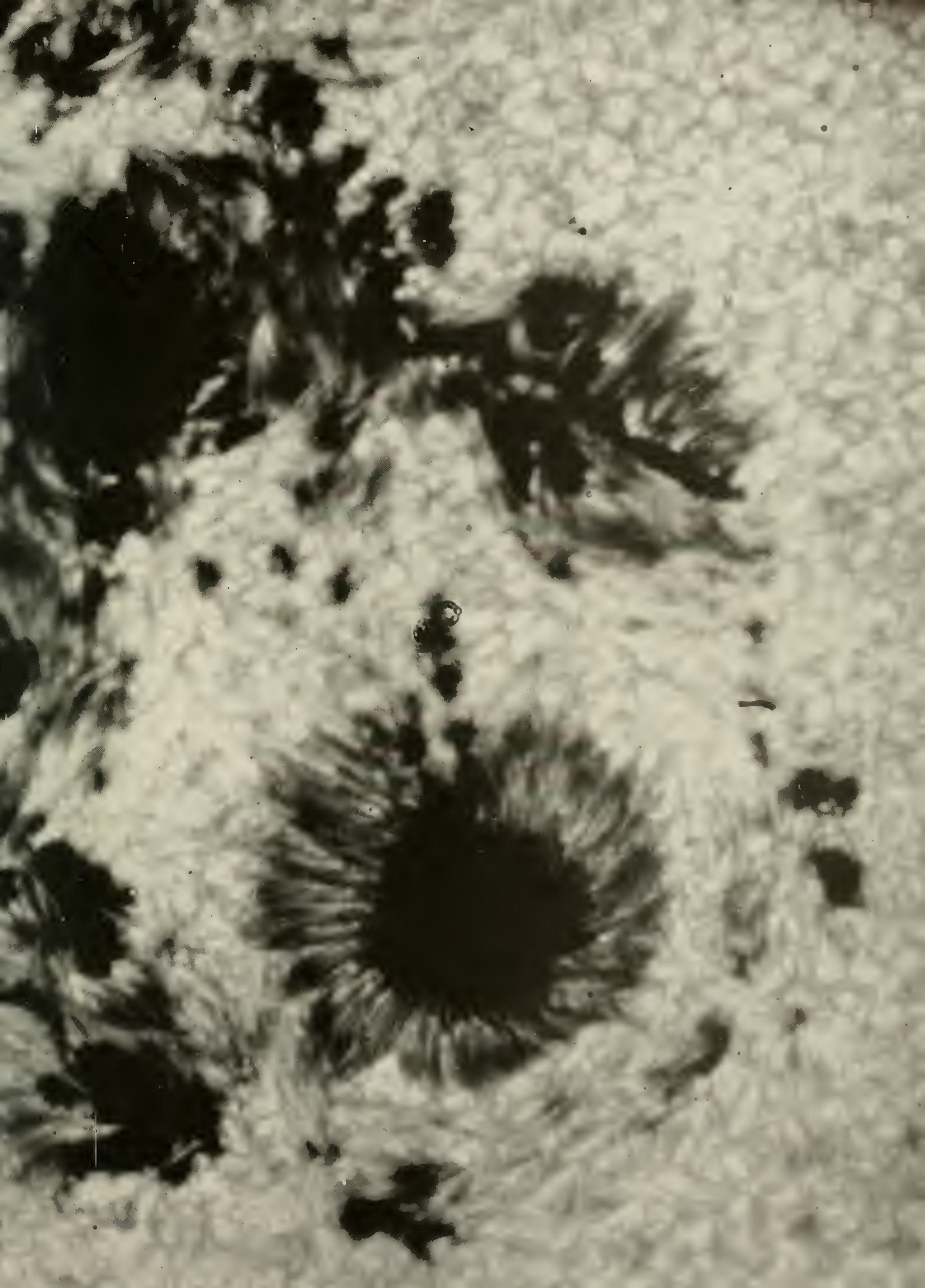
Further answers may lie in new studies of the dynamics of stratospheric circulation now emerging from the IGY observations. For example, we have just recently learned of the existence of a strong circumpolar low-pressure system in the stratosphere. Throughout most of the winter, the rotating vortex of this system dominates the circulation over northern latitudes, at heights from fifteen to at least thirty-five kilometers. During the past several years, at least, this vortex has dramatically collapsed in midwinter, sometimes to re-form again before its final disappearance during the spring months; and there are suggestions that the collapse may be preceded by a sudden increase in solar activity. Observations show that a similar circumpolar vortex also exists in winter in the Southern Hemisphere. But, unlike its northern counterpart, the Antarctic vortex appears to be more stable and—at least during the past several winters—has shown no midwinter breakdown.

These analyses plus IGY data should allow us to make more realistic models of the whole atmosphere. With these we could study the effect of various kinds of solar heating at the top of the atmosphere. However, if the solar effect acts only as a "triggering" mechanism on events at lower levels, then rigid, mathematical proof of sun-weather connections may always be difficult. This does not mean that further progress in sun-weather research must wait for improved computing facilities or more reliable upper atmospheric observations. On the contrary, there are many approaches to the problem that have not yet been explored —particularly the much-overlooked experimental approach.

One of the first such experiment that comes to mind is the famous "dishpan" demonstration that D. Fultz initiated at the University of Chicago. Much to the surprise of many meteorologists, both Fultz and H. Riehl have shown that the gross features of atmospheric circulation in a hemisphere can be closely simulated in a rotating pan, partially filled with water, provided that there is a heat source at the rim and a heat sink at the center *(illustration,* p. 604). This analogy to solar heating at the Equator (in the experiment, the edge of the dishpan) and cooling at the Pole (the heat sink at the pan's center) produces wave disturbances and a jet stream in the dishpan that are strikingly similar to those observed in the real atmosphere. The number and amplitude of the waves can be controlled either by changing the rotation of the pan or by varying the temperature gradient from rim to center. One rather preliminary effort to simulate solar corpuscular heating, made some time ago, resulted in a strong increase in the "north-south" component of the dishpan's circulation analogous to meridional air transfers in the real atmosphere. This result is at least compatible with the results of the atmospheric analyses that we described earlier.

These are but a few of the many paths that should be explored in the search for solutions to the riddles facing meteorologists today. We must extend our efforts toward better understanding of our most immediate environment, the atmosphere, for with understanding comes the ability to predict and, perhaps, even to control. The dream of accurate weather forecasts, useful months or years in advance, is a powerful and gripping one. Its potential benefits for agriculture, for health, for the fuel industry, for transportation, for recreation, and a host of daily human activities is overwhelming. Given impetus from an imaginative program of research, long-range weather prediction cannot but show a significant improvement in the next decade. Certainly, much of this improvement will come from a better understanding of the part that variable solar emissions play in our changing weather.

Active sunspots were photographed last August, day after magnetic storm on earth. The pictures, taken by new technique from unmanned balloon at 80,000 ft., are clearest yet.



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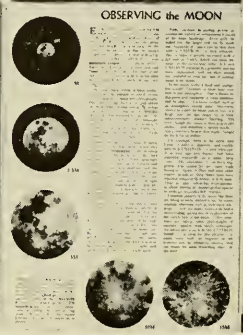
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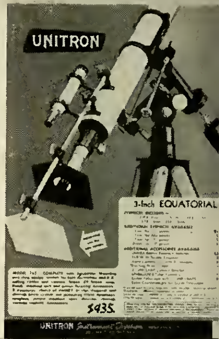
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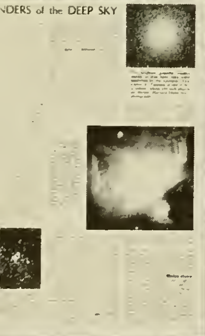
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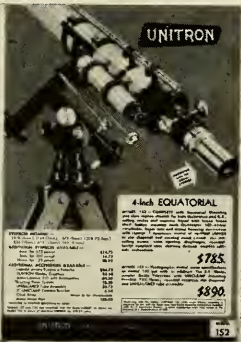
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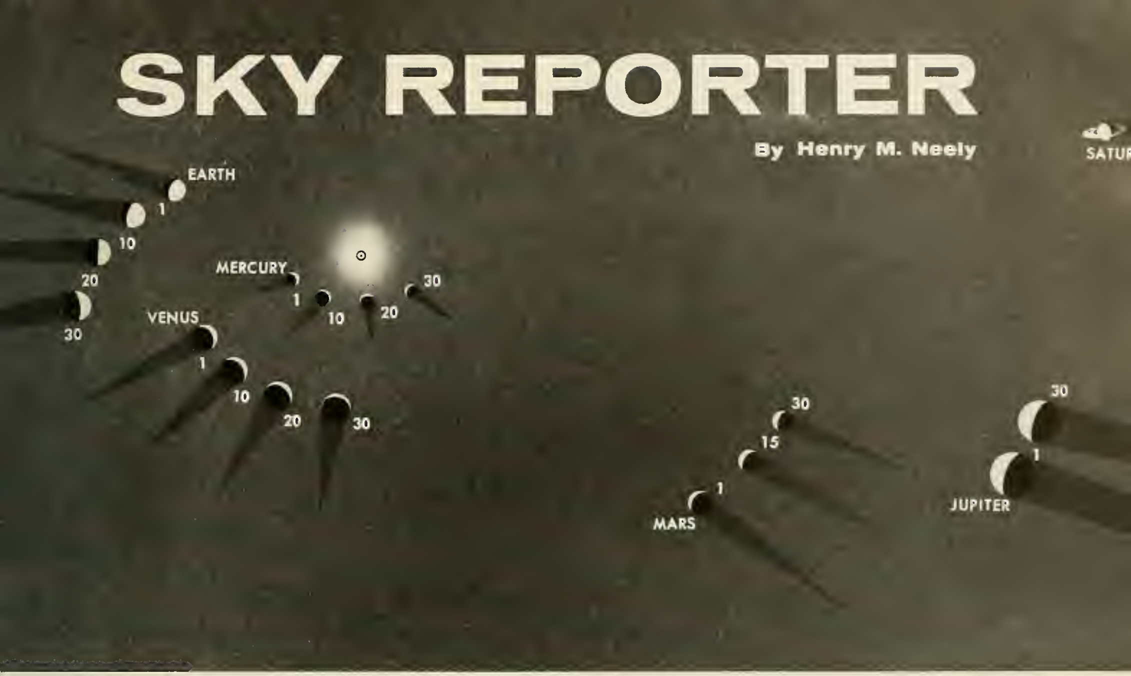
SKY REPORTER

By Henry M. Neely



THIS MONTH would be a good time for anyone who is just starting to study elementary astronomy to be in a space station, far up above the sun, looking down on the earth and the naked eye planets. From such a vantage point, he would be provided with visual demonstrations of the meanings of some words frequently used in texts.

What he would see is approximately represented by the diagram, *above*, although it must be understood that the distances and sizes in this diagram are *not* to scale. The first visual demonstration of an astronomical term that he would observe would come on December 5. On that date, a straight line drawn from the earth through the center of the sun, and then extended beyond the sun, would cut directly through Jupiter. The astronomers say of this configuration that Jupiter is "in conjunction"; conjunction simply meaning "in line with the sun" from a point of view on earth. This same relationship will apply to distant Saturn on December 31 (*see* diagram). On that date, Saturn, in turn, will be in conjunction.

If our elementary student had been a resident of this imaginary space station on November 24, he would have seen the earth, Mercury, and the sun all in a line, with Mercury lying *between* the earth and the sun. This configuration is what astronomers call an "inferior" conjunction. If he remained in the space station until January 26, he would again see the earth, Mercury, and the sun in a straight line—but, this time, Mercury would be on the *far* side of the sun. This is a "superior" conjunction.

An inferior conjunction, therefore, requires that a planet be between the earth and the sun. This obviously requires that the planet be one located nearer to the sun than is the earth: otherwise it could not come between the two bodies. Thus, Mercury and Venus alone among the planets of our system can have inferior conjunctions.

The diagram above also helps to explain the positions of the planets as we will see them from the earth this month. For any of the dates shown, draw a line from the earth through the center of the sun and extend it to the edge of the diagram. Any planet below that line will be a "morning star": its closeness to the line will indicate how much before sunrise the planet will rise. Planets above the line will be "evening stars" and their nearness to the line gives an idea of how long after sunset they will be above the horizon as we view them from earth.

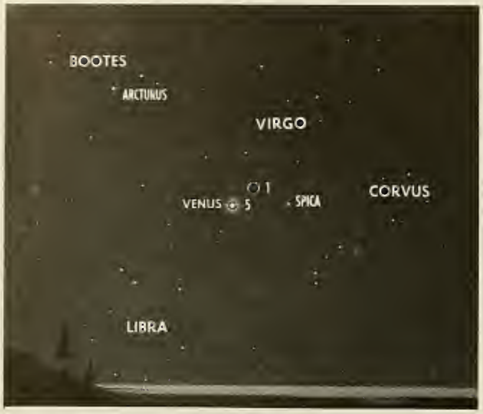
WITH this system, it can easily be seen that Venus is in an excellent position before dawn all month (*see* also the maps on the next page). Mercury circles so near the sun that it is usually lost in the glare but our diagram shows that, on December 12, the line of sight from the earth runs tangent to the orbit of Mercury as it makes its widest angular separation from the sun.

The astronomer calls this the "greatest elongation west" and, for a few mornings around December 12, Mercury may be seen as dawn begins. Its position during this period is shown on the next page. Venus was similarly at its greatest western elongation on November 11.

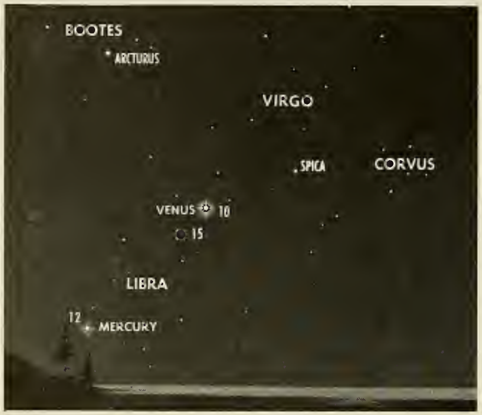
During the first half of this month, Saturn will be on the evening side of—and close to—our imaginary line. This means that Saturn will set shortly after sunset.

After conjunction on December 5, Jupiter will be on the morning side of the line but too close to the sun for good visibility until the end of the month.

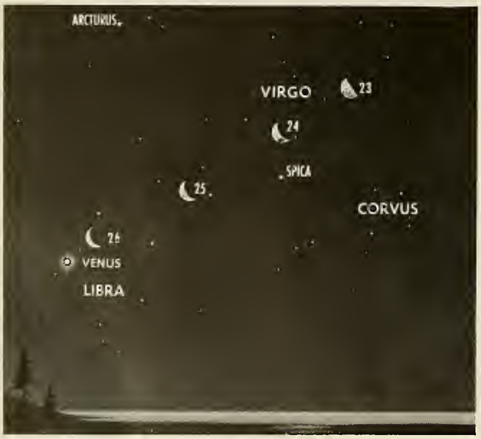
In the first days of the new year, we will witness an unusual event: all five of the naked eye planets will be up above the horizon as the sun rises. However, two of them—Mercury and Saturn—will be too low to be readily visible to observers who live in northern latitudes.



VENUS is shown, *above*, as it will appear during first week of December. Outline circle is position on first of month.



MERCURY joins Venus, *above*, during December's second week. Watch between east and southeast, near the horizon.



DAWN TREAT on Boxing Day, *above*, will be sight of waning moon close to Venus, a "morning star" low in the southeast.

WITH Mars, Jupiter, and Saturn virtually out of our sky picture for December, the planet-hunter who wants to find Mercury and Venus will have to keep early hours these frosty mornings.

Venus presents no problem in location. It is well up long before dawn and is so brilliant as to be unmistakable. Mercury, however, will require strict adherence to a time schedule and, in addition, an unobstructed southeast horizon. Observers in the southern parts of the country will have a much better chance to see it than will watchers in the north, and the person whose observing location is higher than the land to the southeast will be in particularly good position to see the elusive little planet.

Prospects are best on December 12, when Mercury will be at greatest western elongation—a situation that has just been described. But for two or three days before and after December 12, Mercury will be well worth trying for.

The sky pictures for the most interesting siuations this month are shown by the three maps, *left*. In the first *(top)*, the positions are calculated for 6:00 A.M., just before the approaching dawn begins to lighten the sky. Venus then will be almost exactly southeast—quite close to, but far outshining the first magnitude star Spica, in Virgo. Higher up, and to the left, will be Arcturus, one of the brightest stars in northern skies.

The second map *(center)* is calculated for 6:10 A.M., between December 10 and December 15 and is designed to assist in the search for Mercury. The little planet will be quite low, but bright enough to be seen clearly through the usual horizon haze. Binoculars should reveal it even to those whose locations are not particularly favorable.

Late in the month, the waning moon enters this area of the sky, as shown on the third map *(bottom)*. The time is 6:15 A.M. and the most interesting situation will be on the morning of December 26, when Venus and the "thin" moon will be very close together. At that same time, just as dawn begins, Mars, Jupiter, and Saturn will be bunched in an extremely close group, barely above the horizon and not yet high enough to be seen easily.

SINCE most of the important dates for the month are covered in the preceding text, our customary calendar form has been omitted. Only three events not previously mentioned are of particular interest. They are:

December 10 to 15: Usually one of the best of the meteor showers, the Geminids will be spoiled this year by the moon's bright light. These "shooting stars" seem to radiate from the constellation of Gemini, and are at their best from December 12 to 14. But the roll-around map *(right)* shows that the moon will be nearby on all these nights—and will be full on December 14.

December 22-23: A few years ago, a new shower of meteors was discovered; it has never been brilliant, but meteor enthusiasts watch on these dates every year to see whether the shower will grow better or will fade away. These meteors are known as the Ursids, because they seem to radiate from a point in Ursa Minor near the fairly bright star, Kochab, at the tip of the "Little Dipper's" bowl. The moon will not rise until midnight so there should be a few good hours in which to keep watch.

December 22: At 9:35 A.M., EST, the sun will appear to be at its annual farthest point south. This is the solstice and winter will officially begin. At that moment, the sun will be directly overhead for anyone on a ship a few miles east and north of Rio de Janeiro.

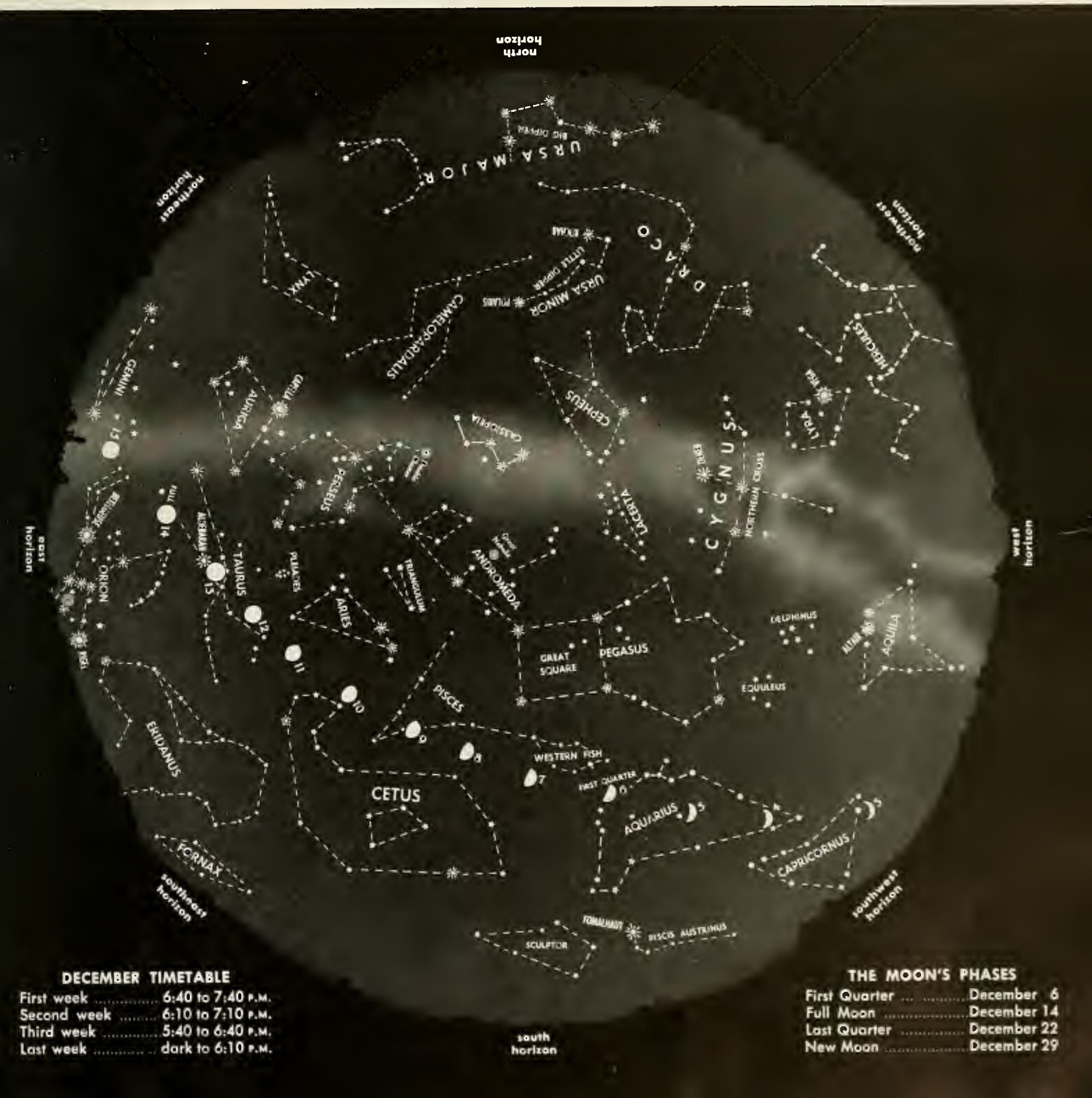
For the more experienced sky watchers—particularly in the western part of the country—the most interesting and dramatic event of the month will be the moon's "occultation"—on December 13—of the first magnitude star Aldebaran, in the constellation of Taurus. An occultation occurs when the moon, in circling around the earth, passes in front of a star and briefly hides it from sight.

Occultations of Aldebaran come in extended cycles that recur on an average of every eighteen years and about seven months. The last series began in August, 1940, and ended in December, 1943. During that period, Aldebaran was occulted forty-three times, but many of these events took place in daylight. The series that began this September will bring thirteen occultations during 1960, but only eight will be visible to observers in North America and at least three of them will occur during daylight.

Mr. Neely, editor of *Sky Reporter* since 1947, now prepares this regular feature for Natural History.

The occultation this month will be difficult for the amateur to see. The moon is full on December 14: special optical equipment is needed to cut out the glare.

These Aldebaran occultation cycles begin when the ascending node of the moon's orbit is near enough to the autumnal equinox. The whole lunar orbit revolves in such a way that the nodes "regress," or circle westward along the ecliptic and go completely around in a period of a little more than eighteen and one-half years. On November 25, the moon's ascending node was only 2°6′ from the equinox. On December 22, it will be even closer.


north horizon
northeast horizon
northwest horizon
east horizon
west horizon
southeast horizon
southwest horizon
south horizon
URSA MAJOR
BIG DIPPER
LYNX
VEGA
LITTLE DIPPER
URSA MINOR
POLARIS
DRACO
CAMELOPARDALIS
HERCULES
LYRA
GEMINI
AURIGA
CAPELLA
CASSIOPEIA
CEPHEUS
CYGNUS
DENEB
NORTHERN CROSS
PERSEUS
LACERTA
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ORION
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TAURUS
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TRIANGULUM
ANDROMEDA
ARIES
RIGEL
DELPHINUS
ALTAIR
AQUILA
GREAT SQUARE
PEGASUS
EQUULEUS
PISCES
ERIDANUS
WESTERN FISH
CETUS
FIRST QUARTER
AQUARIUS
CAPRICORNUS
FORNAX
SCULPTOR
FOMALHAUT
PISCIS AUSTRINUS
15
14
13
12
11
10
9
8
7
6
5

DECEMBER TIMETABLE

First week	6:40 to 7:40 P.M.
Second week	6:10 to 7:10 P.M.
Third week	5:40 to 6:40 P.M.
Last week	dark to 6:10 P.M.

THE MOON'S PHASES

First Quarter	December 6
Full Moon	December 14
Last Quarter	December 22
New Moon	December 29

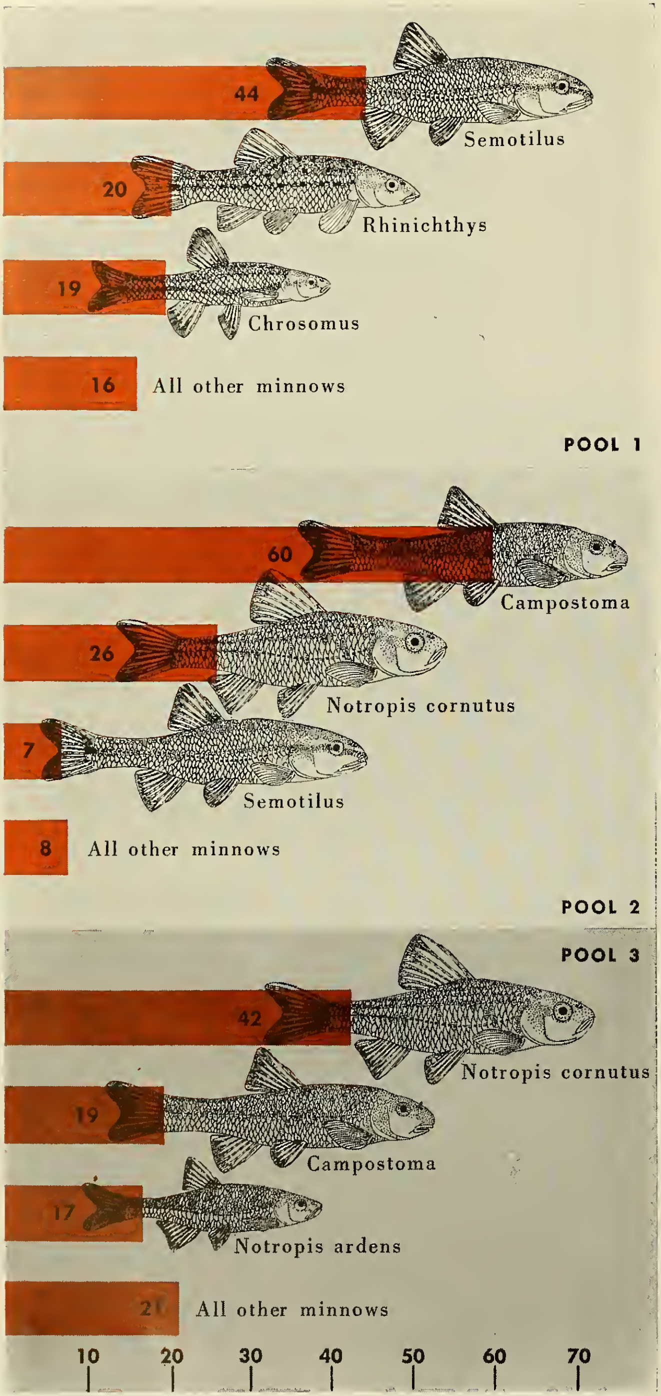
Comparative study

By WILLIAM R. KEM

William R. Kem of Richmond, Indiana, now a freshman at Swarthmore College, was in his last year at Richmond Senior High School when he became a finalist in the 1959 National Science Fair with a study on fish populations, presented here.

Dr. James W. Atz, whose commentary on Mr. Kem's investigative procedures accompanies the paper, is Associate Curator of the New York Aquarium.

This is the second paper to be printed by Natural History in its new program of giving broader circulation to science projects that reached the final competitions of the Westinghouse Science Talent Search and the National Science Fair.



Relationship between first-ranking and second-ranking species among the minnow population (percentage, by weight, *above*) was strikingly similar despite pool size.

During an independent summer study course in advanced biology offered by my local high school in 1957, I began a general introductory study in the field of fish ecology. I selected pools in three different Indiana stream environments, collected and classified their fish, and recorded my observations. At the end of the summer, I had accumulated a notebook of observations, but came to no conclusions.

Later, I decided to utilize this study in a more definite project, the purpose of which was to study some general characteristics of stream fish populations and the changes that they undergo with changes in the size of the streams. In this way, one could find the influence that the size of the physical environment has upon its fish inhabitants. With this purpose in mind, I undertook the measurement of my three pools almost a year after I had collected the fish.

The pools had been selected according to their accessibility, their seinability, the stream size, and whether or not the selection was representative of the general conditions present in the streams in adjacent areas. Pool I, on Lick Creek, is a headwater environment, with a regular rate of flow, clear water, shallow depth, and a bottom of gravel, sand and silt. It is fairly stable in its physical conditions. Pool II, on the West Branch of the Whitewater River, is located in a stream habitat larger than that of Pool I. It is representative of an environment intermediate between headwater and large creek. The rate of flow is greater but less stable; the stream meanders through open areas and has a rocky,

YOUNG SCIENTIST

of the fish populations in three streams of Eastern Indiana

gravel bottom. Unlike Pool I. the water in Pool II is slightly turbid.

Pool III lies in a much larger stream, Nolan's Fork. It has long stretches of open water separated by riffles. a greater width and length. as well as depth, a larger volume of flow, but a slower velocity. Nolan's Fork is characteristic of the larger. deeper streams that run directly into local rivers. Pool III is subject to wide fluctuations in water level; the bottom is made up of small gravel. sand and silt; the water is more turbid. Thus. the three pools are numbered in increasing order of size, turbidity. and instability.

Collecting was accomplished by using a twenty-foot seine with quarter-inch mesh. Two people would work slowly from the bottom riffle to the upstream riffle several times. Then the pool would be seined a section at a time. Seining of the pool continued until very few fish were caught. The fish were preserved in a four per cent solution formaldehyde and eventually placed in seventy per cent isopropyl alcohol as a permanent preservative. The fish were sorted and then identified with the use of the up-to-date ichthyological keys of Gerking (1955) and Hubbs and Lagler (1947).

I TOOK length measurements to determine if the mean length of a species was an indication of its productivity. The standard length—the length of the fish in a straight line from the anterior tip of the snout to the structural base of the caudal fin — was selected as the unit of length measurement. Shrinkage from preservation was ignored due to to its small effect. Such a decrease, I felt, would also be relatively the same for individuals of the same species. The total weight of each species was determined with the use of a gram balance.

Almost a year later, I measured the three pools in order to make calculations of their productivity. Although maximum depth measurements taken at both dates are almost the same. it is possible that there was a slight difference between the 1957 and the 1958 water level. Such a possible change in water level means that my productivity calculations may contain an indeterminate amount of error. If this is true, the productivity results are probably maximum values, since there was an abnormal amount of rain in the spring of 1957 compared to the spring of 1958.

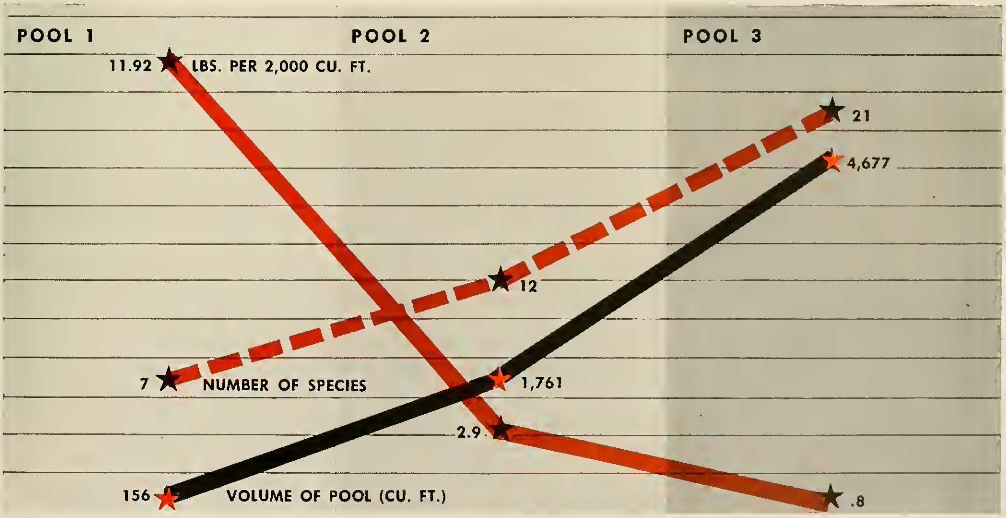
In analyzing the results of this study, it should be remembered that the figures are valid primarily when used for comparisons among the three pools. The following weaknesses in absolute calculations should be noted:

(1) Differences in seining efficiency, due to the type of bottom. Rocky bottoms permit a greater rate of escape for some bottom-dwelling species such as darters. sculpins. and suckers. This. for example. surely explains the low percentage of total weight represented by the darters in Pool II.

(2) Error in the productivity or density estimates because of possible changes in water level.

(3) The percentage compositions of the total weight in Pool III do not present an accurate analysis, for some of the sunfish were able to escape by jumping over the net.

THE three streams sampled were primarily minnow streams. Minnows constituted 69 per cent. 96 per cent and 97 per cent of the total weight, respectively, in the three collections. If present in the pool. suckers were next highest in weight percentage. The darters and sculpins represented a very small percentage in all pools.



NUMBER of different fish species found in each pool increased in rough parallel to increase in pool's volume, *above*. It was found, however, that total weight of fish in proportion to water volume fell off sharply as the size of a pool increased.

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I found that, as the stream environment increases in size, the number of species present also increase, but the weight productivity in relation to area or volume becomes less (graph p. 612).

Comparisons of the mean length measurements of a species with its weight productivity shows that the mean length does not necessarily indicate any trend in its productivity. It seems that another factor, that of age-groups, is involved in the data. If the fish were separated into age-groups, counted, and measured, the results would probably correspond with the data on weight productivity.

The seining efficiency for the minnow populations was very similar for all the collections. Calculations of the weight percentage of each minnow species to the total minnow weight were made in order to determine the changes in the interspecies relationships as the size of the stream changes. The percentage compositions of the minnow populations are shown, graphically on p. 613.

As can be seen, a strikingly close relationship was found between the percentages of the two most dominant species in each collection. In the three pools, the ratio of the first-ranking species to the second was 2.2, 2.3, and 2.2 respectively. This numerical relationship suggests that the two most dominant species are related in a ratio which remains constant despite increases in the size of the stream. I plan to carry out a more complete study of these interspecies relationships in the future.

Through this study, I found that certain changes take place in fish populations as the size of the stream changes. I am now in the position to isolate and analyze these changes, in the hope of finding their underlying causes.

COMMENTARY

POPULARIZATION has inevitably overemphasized the seemingly sensational and romantic aspects of science. Yet, like almost all human accomplishments, scientific research requires large doses of drudgery. Behind the vast majority of its discoveries, both major and minor, lie endless hours of routine observation, counting or measuring—much of it to no immediate avail. Yet even the most routine and seemingly futile work may yield the unpredicted observation or spark the unexpected insight that eventually leads to an advance in our knowledge of the world around us or even of ourselves. This is one of the *truly* romantic things about science.

But the whole truth is that such a happy concatenation of circumstances—the occurrence of a significant event simultaneously with the presence of a mind ready to recognize or interpret it—is rare indeed. We shall never know how many would-be significant data pass unheeded through the mill. We do know that more than ninety-nine per cent of those that are supposed to be significant, and are investigated, turn out to be duds.

These elements of research are represented in the work of Mr. Kem who, in the course of a routine investigation of the fish populations in three Indiana streams, uncovered an unusually uniform relationship between the total weight of the two most prevalent species. If the data from only two of the three streams had agreed with such closeness, this correspondence might well have been considered accidental. It is, however, hard to explain such close agreement among three distinctly different streams on the basis of mere chance.

Mr. Kem did not set out to find this kind of relationship. His first idea was to compare the fish fauna of three representative types of streams. Later, as sometimes happens to experienced investigators, he found that there were additional facts he should have gathered in order to compare the biological productivity of these bodies of water—that is, how much fish they were supporting at the time samples were taken from them. He must have noticed the unusually close correspondence only after studying his data for some time, because it is certainly not apparent at first glance.

STREAM SURVEYS, of which Mr. Kem's investigation is an example, form the very foundation of what we know about the bio-economics and the natural history — that is, the *ecology* — of our running fresh waters. It is obvious that until we find out what species of aquatic life are present in our streams, and how many of them, we are completely in the dark. This holds, of course, for organisms besides fish. A complete stream survey includes the quantitative analysis of all the insects, worms, crayfish, and other creatures that share a stream with the fishes—eating them, providing them food, or otherwise influencing them.

A complete stream survey also includes a detailed study of the physical factors of the environment, of which size is but one. Water chemistry, temperature, rate of flow, and type of aquatic vegetation, and the character of the stream bed are some of the features that play a critical role in determining just what species and how many individuals can inhabit a stream.

Mr. Kem has indicated that he intends to investigate whether the relationship he has discovered will hold for other seasons and places. The probabilities are that it will not. Nevertheless, Mr. Kem would not be a good scientist if he failed to make these necessary tests. In so doing, he is bound to learn more about the intricate interactions that take place between a fish and its total environment — especially other fishes. And who knows what else he may find?

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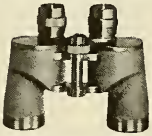

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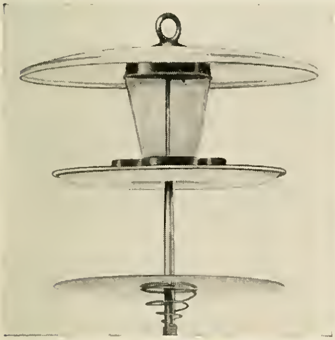

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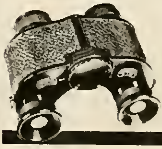

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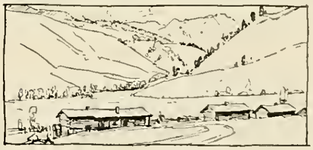

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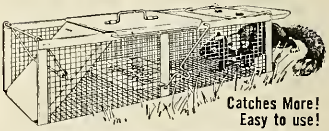

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